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U. S. DEPARTMENT OF AGRICULTURE
WEATHER BUREAU
CHARLES F. MARVIN, Chief

MONTHLY WEATHER REVIEW

VOLUME 47, No. 8

AUGUST, 1919

WASHINGTON
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INTRODUCTION.

The MONTHLY WEATHER REVIEW contains (1) meteorological contributions and bibliography, including seismology; (2) an interpretative summary and charts of the weather of the month in the United States and on the adjacent oceans; and (3) climatological and seismological tables dealing with the weather and earthquakes of the month.

The contributions are principally as follows: (*a*) Results of the observational or research work in meteorology carried on in the United States or other parts of the world, in the Weather Bureau, at universities, at research institutes, or by individuals; (*b*) abstracts or reviews of important meteorological papers and books, and (*c*) notes. In each issue of the REVIEW reviews, abstracts, and notes are grouped by subjects, roughly, in the following order: General works, observations and reductions, physical properties of the atmosphere, temperature, pressure, wind, moisture, weather; applications of meteorology, climatology, and seismology.

The Weather Bureau desires that the MONTHLY WEATHER REVIEW shall be a medium of publication for contributions within its field, but the publication of such contributions is not to be construed as official approval of the views expressed.

The partly annotated bibliography of current publications is prepared in the Weather Bureau Library. Persons or institutions receiving Weather Bureau publications free should send in exchange a copy of anything they may publish bearing upon meteorology, addressed "Library U. S. Weather Bureau, Washington, D. C.," in order that the monthly list of current works on meteorology and seismology may be as complete as possible. Similar contributions from others will be welcome. Bibliographies of selected subjects are published from time to time in the REVIEW.

The section on the weather of the month contains (1) an interpretative discussion of the weather of North America and adjacent oceans, and some notes on the weather in other parts of the world; (2) details of the weather of the month in the United States; and (3) brief discussions of weather warnings, rivers and floods, and weather and crops. There are illustrative charts. The climatological tables comprise summaries of the weather and excessive precipitation data for about 210 stations in the United States, and summaries of the weather observed at about 30 Canadian stations.

It is hoped that the meteorological data hitherto contributed by numerous independent services will continue as in the past. Our thanks are due especially to the directors and superintendents of the following:

The Meterological Service of the Dominion of Canada.
The Meteorological Service of Cuba.
The Meteorological Observatory of Belen College, Habana.
The Government Meteorological Office of Jamaica.
The Meteoroolgical Service of the Azores.
The Meteorological Office, London.
The Danish Meteorological Institute.
The Physical Central Observatory, Petrograd.
The Philippine Weather Bureau.

The seismological tables contain, in a form internationally agreed on, the earthquakes recorded on seismographs in North and Central America. Dispatches on earthquakes felt in all parts of the world are published also.

Since it is important to have as the name of the month appearing on the cover of the REVIEW that of the period covered by the weather discussions and tables rather than that of the month of issue, the REVIEW for a given month does not appear until about the end of the second month following.

Supplements containing kite observations and others containing monographs or specialized groups of papers are published from time to time.

NOTES TO CONTRIBUTORS.

Authors are requested to accompany their papers submitted for publication with a brief opening synopsis. When an article deals with more than one subject—as, for example, a mothod of measurement—some experimental results and a theory, each subject should be summarized in a *separate paragraph*, with a title which clearly describes it.

When illustrations accompany an article submitted for publication in the MONTHLY WEATHER REVIEW, the places where they should appear in the text should be indicated, and legends or titles for them should be inserted just after the end of the article. As far as practicable the illustrations when accompanied by their legends should be self-explanatory—i. e., the data on them should leave no doubt of what they are intended to convey.

SOME WEATHER BUREAU PUBLICATIONS.

Serial numbers of Weather Bureau publications	Free.
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Notes on the climate of France and Belgium	Free.

As the surplus of MONTHLY WEATHER REVIEW, February and April, 1919, is limited, recipients who do not care to retain their copies will confer a favor by notifying the Chief of Bureau, who will arrange for the return postage.

FIG. 1.—Late afternoon, double layer of clouds: broken alto-stratus and stratus.

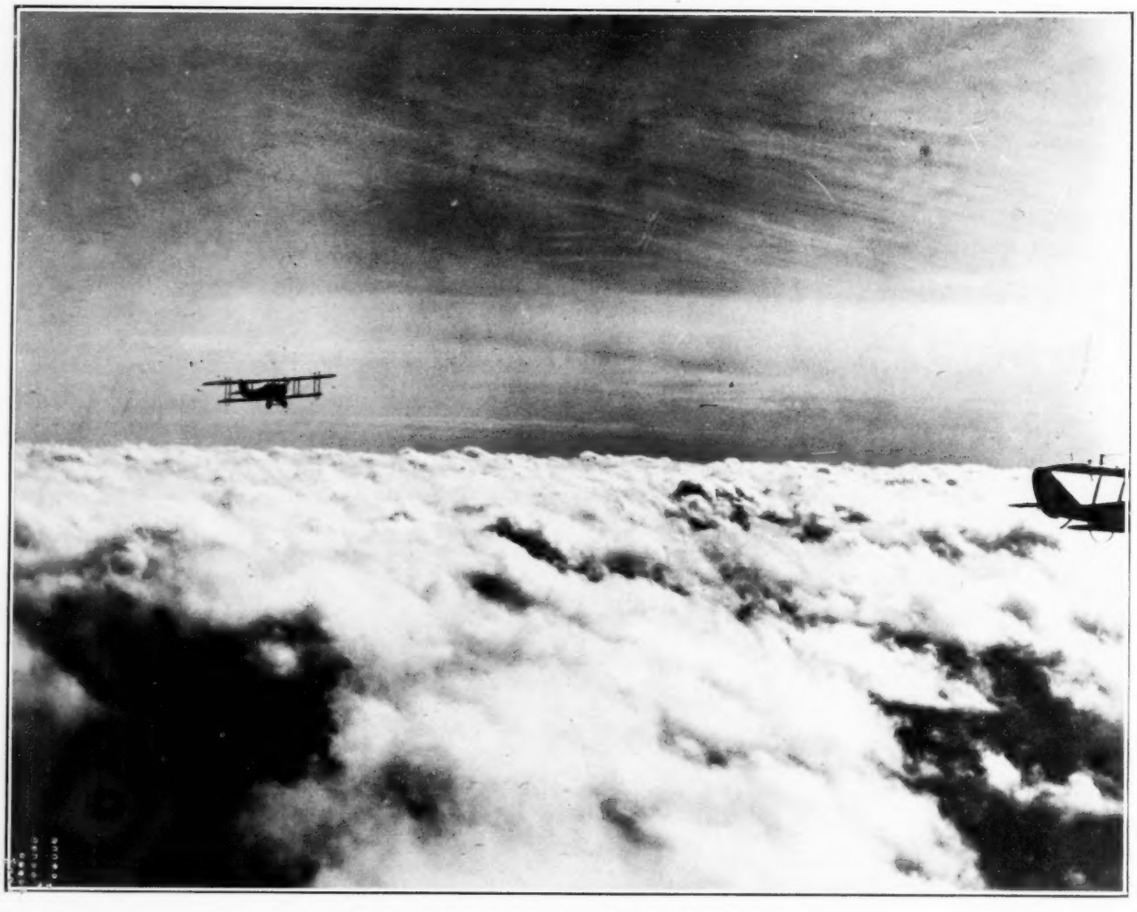

FIG. 2.—Thick layer of strato-cumulus; cirro-stratus above.

MONTHLY WEATHER REVIEW

CHARLES F. BROOKS, Editor.

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EFFECT OF WINDS AND OTHER WEATHER CONDITIONS ON THE FLIGHT OF AIRPLANES.

By CHARLES F. BROOKS and OTHERS.

[Dated: Weather Bureau, Washington, Oct. 3, 1919.]

SYNOPSIS.—By means of data collected from numerous sources relative to meteorological phenomena observed in flying, an attempt is made in this paper to explain on a scientific basis, for the benefit of the aviator, the phenomena he has observed, and at the same time to gather from these experiences such facts as are of value to the meteorologist in amplifying his knowledge of what actually exists in the upper air.

The disturbances of the air due to daytime convection are one of the prime sources of bumpiness. Especially on hot summer days do strong, rapidly rising currents of air penetrate to great altitudes and, where encountered, jolt the aeroplane. Where the cooler air is descending, the effect is similar to that of falling into a "hole." The height to which the effects of surface roughness extend when the wind is blowing depends upon the speed of the surface wind and the height of the obstruction.

In the free air, aviators' observations show how the layers of air flow over one another, the interface sometimes being marked by clouds and sometimes entirely invisible. At such levels are encountered billows or waves, and considerable difficulty is sometimes experienced in flying through such regions. Clouds, rain, and fog all contribute to the discomfort and danger of flying.

Perhaps the most interesting are the experiences in the thunderstorms and the up-and-down winds which accompany such storms. As the driving wedge of cold air at the surface advances ahead of the storm, the air into which the storm is moving is forced upward. The maximum turbulence is found in the region of the squall cloud, but the force of the rising air ahead of the storm is sufficient to carry up airplanes considerably, in spite of the efforts of the pilots to keep the nose of the plane down. The dangers from lightning and hail, are also quite as important as those from the capricious winds.

INTRODUCTION.

In a mutual discussion of the meteorological aspects of aviation the aviator and the meteorologist obtain much valuable information. The aviator tells the meteorologist his experiences with various air conditions, and the meteorologist attempts to explain how such conditions are produced, how best to avoid the unfavorable ones, and how to take advantage of the favorable. Furthermore, the information which the aviator can give the meteorologist helps to explain many doubtful weather phenomena which the meteorologist has not been able to observe personally at close range. To obtain facts essential for this paper, about 50 experienced aviators have been consulted. In several cases Signal Corps meteorologists themselves have made flights or have prevailed on others to investigate carefully certain points about which further information was needed. In addition, we have used freely the numerous reports, "Meteorological aspects of aviation" written by Dr. Griffith Taylor's student aviators and published in the Australian Monthly Weather Report (**1**); and also have gathered numerous accounts of aviators' experiences published in aeronautical journals and elsewhere.

We have attempted to classify these experiences under the headings: (1) surface winds—effects of local heating, and effects of surface configuration; (2) winds of the free air, turbulent wind boundaries, and flying in clouds and rain; (3) thunderstorms. With each group we have offered explanations. The explanations are, in a large part, presented here without any claim to originality; most are embodied in numerous papers which have already been published here and abroad.[1] In quoting the assertions of aviators the authors do not necessarily subscribe to the entire correctness of the inferences carried or implied.

SURFACE WINDS—LOCAL CONVECTIONAL CURRENTS.

Experiences of aviators.—A most common experience of aviators is daytime bumpiness. The bumps in the air may be described in terms of those felt while riding in different kinds of automobiles on roads of varying roughness.

The aviator may be experiencing moderate bumps and suddenly encounter one sharp enough to "throw the fire extinguisher into my lap" or to "set the ship nearly up on end." Then there may be a little more smooth flying until suddenly the support seems to disappear, the propeller appears to give no headway, and down goes the airplane. A bump may announce the bottom, and the aviator slowly climbs again to his proper level. As seen from the ground on a "bumpy" day, the airplane tilts from side to side to a maximum of 30° from the horizontal, and now and then some sharp up or down motion is discernible. The tilts may give the ship a side slip, which will sometimes be sufficient to remove it from one side of a V formation to the other. When such a side slip occurs too near the ground, one of the airplane accidents characteristic of a hot day in the South occurs.

In general, there appear to be differences of opinion among pilots as to the intensity or magnitude of the vertical movement on bumpy days; this is probably due to the different localities in which the flying was done, or to the pilots' experience. (Experienced pilots are usually the most conservative.) It has been suggested that observers are much more sensitive to these atmospheric phenomena than the pilots, since they have not the management of the plane to occupy their attention. All say that for ordinary bumps a change of 50 feet is common. A change of 200 feet is experienced at times, and occasionally an aviator comes in with a story of having risen or fallen 500 feet. Others have reported sudden drops of still greater magnitude, but it is possible that only the initial fall was due to the bump and the consequent loss of altitude was due to the aviator's inability to right the airplane immediately. The larger and faster the airplane the less is the change of altitude due to bumps. Most of the aviators say that unless flying in formation, it is impossible to tell the amount of up or down motion with a bump or in a "hole" without watching the altimeter. Flying in a squadron formation on a bumpy day in Texas is described as an interesting

[1] See Bibliography on p. 532.

sight, but a difficult performance. The different ships are going up or down and getting out of formation continually. An aviator who was flying second on one leg of a V said that the leader, who was about 100 feet in front and a little off to the side, went up suddenly about 300 feet, but that *his* ship kept on the same level and felt no disturbance. On another occasion the air being very bumpy, the first airplane in a V formation suddenly rose 300 feet, and a few seconds later the second did the same. Evidently the edges of the conditions which caused bumps are at times very sharp.

Most bumps in the air occur near the ground and on bright, hot days. In the northeastern United States, 3,000 to 5,000 feet is the upper limit of bumpiness on a summer day, though in very hot weather, bumpiness, sometimes extreme, occurs at elevations even above 8,000 feet. In Texas the air is bumpy sometimes to more than 10,000 feet. In winter the usual limit of bumpiness at Ellington Field, Tex., is 1,500 to 2,000 feet. Ordinarily, however, the extremely bumpy conditions are within 500 to 2,500 feet of the ground or just under and about cumulus clouds. For example:

> A cloud of the cumulo-nimbus type is often met with, and, as a rule, to avoid it the engine is throttled down, and a dive is made some 20 to 50 feet below it. As the machine assumes its normal flight path again, while under the cloud, it is subjected to very strong gusts, sometimes spasmodic in duration and at all times variable in direction. Again, under the same cloud another movement of an oscillatory character is encountered. The oscillations, as a rule, are very slow, for they produce in the aeroplane considerable undulation about the pitching axis; thus, for a few seconds the machine is subject to a strong lift, then the nose is forced down, sometimes causing a steep dive. Still yet another distinct and even more interesting disturbance is met here, in the shape of a rapid vibratory effect on the machine. This is probably due to a horizontal head or following wind whose speed rapidly alternates between a low minimum and a high maximum—*Lieut. F. H. McNamara, Australian Monthly Weather Report August 1913, page 431.*

In the interior of Texas flying is generally not attempted in the hottest hours of bright summer days because the air is dangerously bumpy. Here is a case of a crash ascribed to "heat bumps":

> Lieut. F. W. Keller and Sergt. E. Chapman on leaving Clarksdale, Miss., June 17, 1918, "had difficulty in attaining altitude because of the heat waves. [Their airplane] while making a turn, went into a tail spin and crashed [killing both men]."—*Assoc. Press.*

It is impossible to say what proportion of flying fatalities have resulted from vertical currents on hot days. Aviators are unanimous in saying that Texas has the bumpiest flying of any part of the United States.

The places where bumps occur are well known to aviators. Roads, railroads, edges of plowed fields, forest edges and clearings, barn roofs, hangars, ditches, borders of swamps, shore lines, all give bumps, the sources of which can be identified generally to 700 or 800 feet, and on calm days occasionally to 2,500 and even 3,500 or more feet. The bumps associated with macadam roads and other hot places are not necessarily directly over the road, but to leeward at a distance depending on the velocity of the wind and the height of the airplane. The effect of ditches seems to depend on the nature of the ditch. Some aviators at Rich Field allowed for fall of about 15 feet in crossing a sunken road in the vicinity of the field. An aviator said that over a certain ditch near the field where he was flying he always experienced a considerable bump; but he could not say whether or not there was a slight fall before the bump. Railroads have the same effects as roads. Creeks seem to have down currents over them. The following was told by Lieut. Morgan, one of the most experienced flyers at Carruthers Field:

> His airplane which had landed on the bank of small stream on a very hot day had considerable difficulty in rising because the propeller did not seem to take hold of the light air. After the ship had risen perhaps to 500 feet it suddenly began to fall. The propellor, even though going at 1,400 revolutions per minute, seemed to do nothing, and the elevators did not respond until the ship was 50 feet from the ground. Then conditions became normal and the airplane began to rise slowly after having fallen to a height of only 10 feet.

An aviator trained at Rich Field said that he did most of his flying over the open woods just south of Waco; he chose the woods because he feared less from the bumpy condition of the air over the woods than from collisions with others over the smoother fields. Over these woods the bumpiness extends with a certain degree of roughness to 1,200 or 1,800 feet, and is perceptible to 2,500 feet. By common agreement, a green field is said to be the best landing place and a plowed field the worst (if forests and rough ground are excepted). In the air, cumulus clouds and the region immediately under the clouds are generally avoided because of their well-known rough character.

As to conditions along the coast, the following statement by Donald B. Kimball, a naval aviator, shows the effect of difference in convection over water and land surfaces:

> On clear, hot days in summer a light breeze off the ocean will often spring up in the morning, the velocity of which increases toward afternoon. Such days make ideal flying for seaplanes if the pilot keeps his machine clear of islands or peninsulas. The air over the shore line of islands or protruding necks is especially treacherous on hot days, for violent bumps may catch the pilot unawares after navigating through the smooth air over the ocean [especially in such places where the water is rather cold relative to the beach, as at San Diego, Calif. The shoreline bumps on Chesapeake Bay, and the Gulf of Mexico may be scarcely noticeable in late summer.] As a rule, the depth of these bumps extends noticeably to about 1,500 feet, very rarely above 2,000 feet, the violence varying indirectly with altitude. These conditions are somewhat altered if cumulus clouds tend to form. The region just under and within the clouds is probably bumpiest of all and there appears to be a sharp decline in violence on climbing above the clouds. On a clear, hot day it is not an uncommon feat for a perfectly balanced machine to fly several minutes at altitudes under 1,000 feet without having the foot controls moved. On such a day I once even saw a pilot step from the front seat to the wing and thence to the rear seat at an altitude of about 75 feet. Such a feat would be almost suicidal in land flying on a hot day.

Otto Neumer, of the Signal Corps Meteorological Service, in discussing typical flight conditions over the head of Chesapeake Bay in winter, states that convectional currents or eddies have little effect upon the movement of the plane, even on passing under or through cumulus clouds. The crossing of the shore line is practically imperceptible.

Explanation of bumpiness.—The local vertical currents which occur on warm days are the result of the unequal heating of the lower air. The air next to the ground gets hot; and, therefore, expands. Over a bare, dry field the heating is greatest. Thus, the surface air locally may become considerably lighter than the cooler air at the same level or even above; and so at the first opportunity some of this heavier air moves laterally or comes down and forces some of the lighter air to rise. On a quiet day at the earth's surface the movement of this cooler air is marked by light, variable winds interspersed with calms. The process of displacement is intermittent. When there is a wind blowing, the occasions when the cooler air moves toward the warmer places are marked by gusts or slack wind. These gusts are the result not only of the combined strength of the horizontal components of convectional winds and of the general wind, but also of the quick, down movement of air, which has a higher velocity than the friction-limited wind next to the ground.

The reason for the bumpier conditions in the middle of the day and for the greater bumpiness in Texas than elsewhere is now apparent—the hotter the lower air relative to that above, the stronger are the convectional currents and the gustier the wind. The reason for the decrease in bumpiness aloft is that near the earth there are likely to be the steepest temperature and wind velocity gradients. Again, the upper limit of bumpiness is the upper limit of the convectional columns of detached masses of rising air; and in much of Texas, at least, the tops of the convectional upcurrents are marked almost daily by the tops of cumulus clouds. (Cf. figs. 6 and 7.) The locations of bumps over roads, railroads, plowed fields, open spots in woods, etc., depends on the differences in the

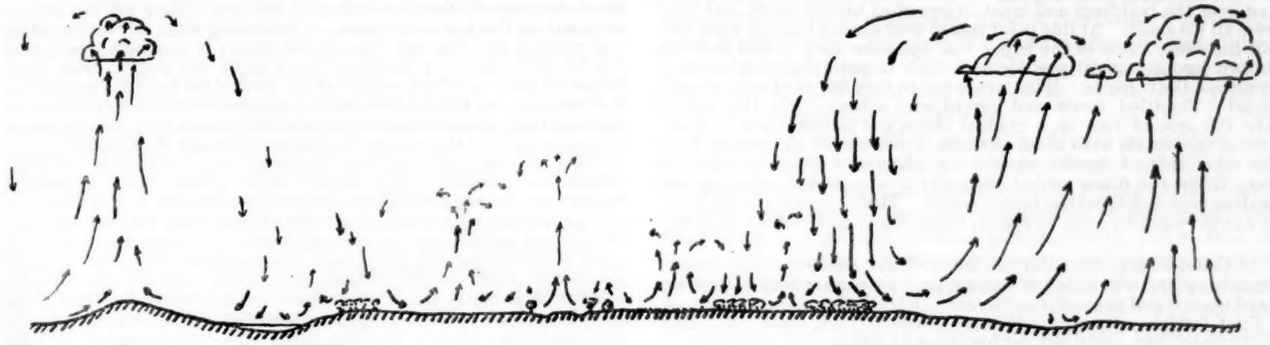

FIG. 7.—Local convectional currents on calm day.

degree of heating of different parts of the landscape. The road gets hotter than the fields on either side, and so the air from both sides flows toward, and displaces upward, the air over the road. (A, fig. 7.) Plowed fields are likewise hotter than the surrounding fields, because their dark, loose surfaces absorb so much more heat, and conduct downward so much less heat, than the surfaces of unplowed fields. Open woods favor bumpiness because some parts become hotter than others. (B, fig. 7.)

Isolated hills, especially short or conical ones, should be avoided during warm, still days, for on such occasions their sides are certain to be warmer than the adjacent atmosphere at the same level and hence to act like so many chimneys in producing updrafts. (C, fig. 7.)

The rising currents are interesting, not only because of the way in which they disturb aeroplanes, but also because they may be utilized by aviators who are trying to make altitude in the shortest time. Many use a rising air column that forms the cumulus, but they claim that many accidents have occurred because of the uncertainties of its direction and action. "Measurements on pilot balloons," says Prof. Humphreys, (**2**) "and also measurements taken in manned balloons, have shown vertical velocities [of convectional currents] both up and down, of more than 3 meters per second. The soaring of large birds is a further proof of an upward velocity of the same order of magnitude, while the fact that in cumulus clouds, water drops and hailstones are not only temporarily supported, but even carried to higher levels, shows that uprushes of at least 8 to 10 or 12 meters per second not only may, but actually do, occur." An aviator who has flown over an active forest fire never does so again, if possible. "There are, then, upward currents (some of which might be called 'air fountains') of considerable velocity whose sides at times and places may be almost as sharply separated from the surrounding atmosphere as the sides of a fountain of water, and it is altogether possible for the swiftest of these to produce effects on an aeroplane more or less disconcerting to the pilot."

Down currents, marking the movement of relatively cool air over ponds (D), lakes, and clumps of trees (E, fig. 7), do not have the marked velocity of upward currents, but are more dangerous. Their boundaries may be sharp enough for an airplane to fly with one wing in and one wing out of the descending current, as over a reservoir in a wheat field in France.

Down currents may extend up to 6,000 feet over woods. Stunt fliers try to get into a rising column for a tail spin; and they say that a "hole" or "pocket" (i. e., a down current) is often fatal. Perhaps down currents were responsible for some of the 35 per cent of training fatalities ascribed to tail spins during the war. In diving, a very thrilling sensation is encountered if the ship enters a down current—the airplane seems to drop away from the pilot.

Other air movements, which are perhaps equally distressing to aviators, are the mountain breezes down river valleys or other low portions of the country. These winds, sometimes of gale force locally, may be met very suddenly from almost calm air in approaching the mouth of a valley at times when the earth is cooling by radiation.

EFFECT OF TOPOGRAPHY ON WINDS.

The effects of heating and cooling of the earth's surface upon the flow of air is not the only cause of turbulence, for there is the effect of topography, which introduces phenomena quite as dangerous and distressing to the airman as convection.

Aviators' experiences.—Roughnesses (including trees and buildings) of the surface produce eddy motion, which in a moderate wind will reach to 1,000 or 2,000 feet and in a strong wind to 3,000 feet or more. Extremely rough conditions are experienced in a gale, as the following accounts show:

Subject: Report [to Post-Office Dep't] of flight from Philadelphia to New York, March 28, 1919.

Left Bustleton at 2:15 p. m. March 28, 1919, in plane No. 30, Curtiss R-4. Wind velocity, reported by Philadelphia Weather Bureau, 48 miles per hour; direction approximately 300° [WNW.]. Climbed to 3,000 feet before reaching Trenton. Steered compass course of 25°, allowing 40° drift angle. Severe bumps felt at all altitudes. Looking ahead snow could be seen. Directly to the rear, atmosphere clear. Passed over Trenton at 2:30. Having a short time before run into snow, which made it necessary to fly at 1,000 feet, at which altitude could just see the ground. Could not see enough of the ground to recognize any landmarks. Flew entirely by compass.

The next landmark picked up was the Woolworth Tower, New York City. Passed over it about 300 feet to the north; altitude about 900 feet. No very severe bumps felt directly over the city, but when passing over Brooklyn very severe bumps were encountered. These

threw the plane about to such an extent that I was unable to watch my compass for several minutes. Extreme aileron and rudder were needed a number of times to bring the plane back to normal flight. Flew with motor wide open during this time (1,600 revolutions per minute).

While passing over Brooklyn the motor cut out three times. Turned on the gravity tank and it picked up again immediately. Then shut off the gravity tank each time it came back. Presumably this was caused by the severe bumps. One pocket over Brooklyn let the plane drop approximately 100 feet. It was so rapid that I was thrown full weight against the safety strap.

The snow became heavier, and in order to see the ground had to fly below 500 feet. The air continued very rough, and was only able to look at compass occasionally. At about 3:05 picked up a railroad and attempted to follow it, thinking that it might lead to Jamaica, but the country was not familiar and it was very difficult to follow the rails. Do not believe I was more than 200 feet. The air was very rough.

At 3:15 decided to pick a field and land. Attempted to do this, but on seeing a field would be driven past and it would be lost before I could turn and land. Then headed around into the wind and flying just over the buildings and trees, approached several fields, but they were all too small. At this point passed over a small body of water and felt the worst bump of the trip. Was not more than 80 feet and was thrown into a vertical position and back to normal almost before I could use the controls. What appeared to be a fair field was directly ahead. Throttled motor and zumed over a fence. On the farther side the ground rose in a gradual slope, and pulled back to land. Just as the wheels were about to touch, a current of air coming from the other side of the hill caught my plane and lifted it about 20 feet. Then the plane settled vertically to the ground, crushing the landing gear and breaking the propeller. This occurred at 3:20 p. m. on a field owned by John C. Baker, Great Neck, L. I.—*John M. Miller.*

At College Park, Md. [Mar. 28, 1919].—Pilot Bissle rose only 50 feet when his plane was forced downward as if some giant had placed his hand upon it and pressed it earthward. His landing gear was smashed.

Pilot DeHart, attempting to leave Belmont Park, New York City, for Philadelphia, could not get his plane off the ground on account of the downward "swirls" of the wind.—*Washington Post, March 29, 1919.*

During a gale the edge of the woods near Houston, Tex., is marked to a height of 1,000 or more feet. Bad bumps have been felt 2,500 feet above and to leeward of hangars on a windy day.

Neumer reports that on days with high winds in eastern Maryland "the air [up to 10,000 feet] seems to be moving in great horizontal eddies or rolls similar to the rolling of ocean waves. The airplane rocks just like a rowboat in the sea."

Such motion is sometimes sufficient to produce seasickness. A case occurred in southeast Texas in the spring of 1918: and another on a mail plane flying from Paris to London in the summer of 1918—"Owing to the straight head wind and deep air pockets, my observer and myself were really seasick, as though pitched and tossed on a heavy sea," said Lorgnat after landing. [1]

Many pilots have been questioned regarding the effect of topography upon the action of their planes at various altitudes. In addition to the natural configurations of the ground, there are also the effects introduced by buildings, groves of trees, and other obstacles over which the wind must pass. The general opinion is that these effects do not extend upward nearly so far as strong convection does, except, perhaps, in very rough, mountainous country or with winds of gale force. It appears also that the altitude to which such disturbances may extend is proportional in general to the wind velocity and the size of the surface irregularities. A combination of a strong north wind and bright sunshine on June 13, 1918, caused bumpiness which was extreme even as high as 6,500 feet, the maximum altitude reached by J. C. Edgerton on his mail plane flight from Washington to Philadelphia on that day.

[1] Note in Scientific American, Aug. 24, 1918. p. 147.

Here are some aviators' accounts:

Almost invariably offshore winds are accompanied by bumps and eddies which cause fatiguing flying. A 10-knot shore breeze makes more trouble than a 20- or possibly 25-knot sea breeze. Evidently this is due to the uneven contour profile of hills, trees, and houses on the land as compared with the sea.

Air bumps from offshore breezes appear to be of a different nature from those occurring over islands in a sea breeze. Under the former conditions the bumps come in gusts and in fairly steady succession. An inexperienced pilot may attempt to keep his machine on an even keel by adjusting the controls for each bump separately, but he soon learns that control, especially with his "ailerons," is practically unnecessary. Alertness in the use of "elevators" is always advised by the instructor. The golden rule of flying is, "Retain flying speed;" therefore the bump which raises the nose of the machine and diminishes the speed must be balanced by a corresponding lowering of the elevators to regain that speed.

Bumps from gusty offshore breezes extend to varying heights. I have encountered them as high as 5,000 feet. They are not always strongest at the lower altitudes. I have seen days when the riding was rougher at 1,500 feet than at 500 feet. It is rather treacherous "to be off" close to a protected shore in an any degree brisk shore breeze for there is a sharp outline at the level of the height of protection. For instance, in taking off toward a hangar, it is not uncommon to pass suddenly from a relatively smooth region to a very bumpy one in swooping up over the edge of the hangar.—*Donald B. Kimball.*

When passing over buildings, groves of trees, or similar obstacles, bumps are generally experienced, their extent being influenced mainly by the strength of the wind. As obstacles of this character are approached with a following wind the machine will lift and drop with equal suddenness on the other side. If approached head to wind the converse will take place—the machine will probably drop, sometimes nearly to the ground, just before reaching the obstacle, and rise as it leaves it. This seems to be due to the fact that when the wind strikes the obstacle it shoots upward. [Fig. 8.] It would be difficult to say what height this updraft generally reaches, but the writer's experience is that it goes up well above the actual height of the obstacle, and is "flattened out" on the other side, where there is often an unmistakable down current.—*Lieut. S. W. Addison.* (1)

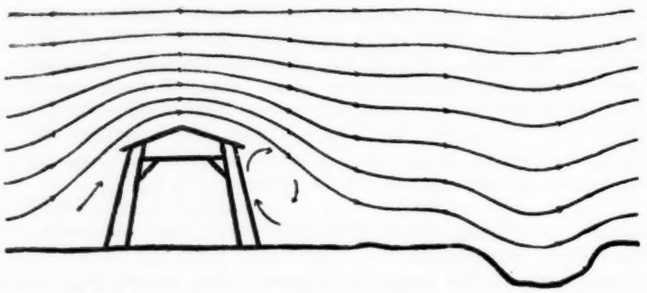

FIG. 8.—Effect of minor surface irregularities on lines of wind flow in a light wind. (From Linke. (10))

The deflected vertical currents consequent upon a surface breeze meeting a belt of trees have often lifted the writer's machine, just in the same manner as a long ground roller does a small boat. This is easy to anticipate when a breeze is noticeable on the ground, but is at first apt to come as a surprise, when on the ground practically no air movement can be detected.—*Capt. H. H. Slorrer.* (1)

A wind makes flying much harder for the airman, not because of the actual wind itself, but on account of its constantly changing velocity and direction. The change of direction of a wind is its worst feature, and causes the machine to "yaw" badly, and so makes it difficult to keep the machine on its course. The wind also changes in direction vertically, and, when we experience this change, the equilibrium of the machine is upset. When flying at a low altitude I have noticed that any irregularity on the surface will cause a change of direction upward or downward and cause the machine to rock, sometimes very badly. If the objects on the ground are of a prominent nature, such as the many belts of trees on the aerodrome, I have experienced a condition which causes the machine to "flop" about in all directions, and is most distracting. I attribute the cause of this to a horizontal eddy being formed near these objects.—*D. P. Flockart.* (1)

The turbulence caused by hills or mountains depends largely on the local topography and on the winds concerned. Point Loma, near San Diego, Calif., gives birth to marked turbulent conditions over and to leeward of it.

Dr. F. A. Carpenter describes the conditions as follows (he was in an airplane at 2,000 feet altitude headed seaward toward Point Loma): [1]

Suddenly there were two distinct "wallops" and I felt the fuselage beneath me respond as if struck by a stuffed club. There was evidently first a surge then a drop, and it was the descending current of air that deprived the airplane of the supporting medium, hence the shock. * * * Although this peninsula (Point Loma) is less than 500 feet high, it so effectively deflects the prevailing northwesterly wind that the upward surge has been noticed by aviators at an altitude of 4,000 feet. It is no wonder, then, that these descending winds, called "woollies" (from their churning up the water into isolated masses which look like tufts of wool), are dreaded alike by yachtsmen and birdmen. They have been known to carry away topsails from too closely venturing schooners, and student aviators always give the vicinity of Point Loma a wide berth.

An aviator flying at 3,500 to 4,000 feet inland from San Diego with the wind, passed over some mountains 2,000 feet high. On the lee side he was forced down, or fell, 1,500 feet. The prevailing cloud sheet at 4,000 feet gave from below no notable indication of such a current, but it seems probable that the upper surface would have showed where the wind was up and where down. The upper surface of this "velo" (stratus) cloud sheet is usually uneven; but this aviator on other occasions had not happened to find how to tell from the form of the cloud surface the underlying topography.

The following, from log of balloon flight made by Lieut. W. F. Reed, jr., on flight from Akron, Ohio, to Fredericksburg, Va., September 16–17, 1919, shows how the wind tends to hug the surface in going over a ridge:

6:20 a. m., 2,400 feet.—Passed over sharp ridge. The balloon was allowed to approach the ridge without discharging ballast; it looked as though we would bump the cliffs, but the upward current carried us over the top. The trees on the crest looked at first like mere weeds, but a closer view showed them up as full-grown trees and we could hear the wind rustling through the leaves. We went down with the current on the leeward side at an altitude of 200 feet above ground until we were halfway down.

Going against the wind up over a mountain region the aviator may have difficulty in keeping his altitude. Lieut. Vance reported:

I had one unusual experience with bumpy wind. It was in October, 1918, when I was leading a formation northwest in the face of a north wind, from Birmingham, Ala., to Fayette, Ala., over very hilly country (hills about 1,000 feet covered with forests). I attained an altitude of about 1,500 feet before striking NW. and travelled for more than an hour trying to climb, and actually settling all the time. It was during the forest fires in Minnesota, and all the air was smoky, very dense. All the other flyers of the squadron had the same experience.

At the time when the smoke was over the South, an extensive anticyclone covered the eastern United States—possibly the settling experienced was due to the general downward movement of the air in the anticyclone rather than due to topographic influences.

The air over a mountain region is usually turbulent. Capt. F. N. Bartlett, in a flight from Scott Field, Ill., to Kelly Field, Tex., a year ago had nine hours of difficult flying over the Ozarks between Eberts Field, Ark., and Post Field, Okla. This turbulence attendant upon flying over the Ozarks was strongly manifest in a recent balloon trip from Fort Omaha, in which it was desired to maintain a constant elevation of 5,000 feet above sea level. This was found absolutely impossible and the balloon often was dragged down to within a short distance of the ground, or caused to ascend again, almost out of the control of the pilot.[2] The accompanying balloon at 10,000 feet was but little affected. On windy days over rough topography, bumpiness has been generally observed to 4,000 feet.

[1] The Aviator and the Weather Bureau, San Diego, 1917, pp. 19–20.
[2] See page 535, reference to Lieut. Reynold's account, balloon article.

Lieut. R. O. Searles, the flight commander of the De Haviland squadron, which made the trip from Ellington field to the Pacific coast and back, related that on the 24th and 26th of February, 1919, it was not possible to enter the Grand Canyon with a plane, but that it was easily possible on the 25th. Sergt. E. B. Scott indicates this was doubtless due to the pressure distribution on those dates, for on the 25th the gradient wind was not of great speed and, moreover, conformed with the direction of the canyon, whereas on the preceding and following days the pressure gradient was steeper and the wind direction was such as to produce great turbulence in passing across the canyon. It has been reported that in a strong south wind the back-and-up current of the eddy in the lee of the south wall of the Canyon has carried tin cans up the cliff and into the yard of the hotel. A canyon near Kelly Field, Tex., has the reputation of being a dangerously rough place. The winds are this way and that; now up 100 feet, then down 100 feet. One loses practically all control of the airplane.

Interpretations.— Wind eddies.—"Just as eddies and whirls exist in every stream of water, from tiny rills to the great rivers and even the ocean currents, wherever the banks are such as greatly to change the direction of flow, and wherever there is a pocket of considerable depth and extent on either side, and as similar eddies but with horizontal instead of vertical axes occur at the bottom of streams where they flow over ledges that produce abrupt changes in the levels of their beds, so too, and for the same general reasons, horizontal eddies occur in the atmosphere with rotation proportional, roughly to the strength of the wind. These are most pronounced on the lee sides of cuts, cliffs, and steep mountains; but also occur, to a less extent, on the windward sides of and above large obstructions." (2)

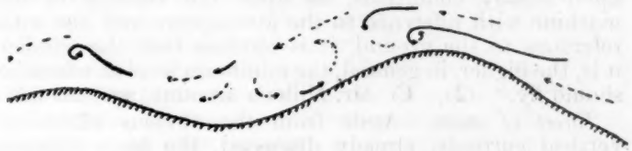

FIG. 9.—Wind crossing a ridge. (From cloud movements observed along the Hudson River, Aug. 4, 1918.)

"The inertia of the wind crossing the mountains tends to carry it on well above the valley or plain beyond, but its drag on the lower air, due to viscosity, deflects it downward. [Fig. 9.] Because of this deflection a foehn wind often strikes the lower slopes with great violence, from which, and mainly because of its dynamical heating, it rebounds to higher levels. Along a belt, therefore, well down the mountain, or even slightly beyond its base, the surface wind may be exceedingly turbulent and violent, while both farther away and also on the higher slopes it is comparatively light. Furthermore, owing to changes in the general direction of the crossing current, or in its strength, or both, the wind belt may shift up or down the mountain or even vanish entirely."—*W. J. Humphreys.*

"The air at the top and bottom of wind whirls is moving in diametrically opposite directions—at the top with the parent or prevailing wind, at the bottom against it—and since they are close to the earth they may, therefore, be a source of decided danger to aviators. There may be some danger also at the forward side of the eddy where the downward motion is greatest.

"When the wind is blowing strongly landings should not be made, if at all avoidable, on the lee side of and close to steep mountains, hills, bluffs, or even large buildings, for these are the favorable haunts, as just explained, of treacherous vortices. The whirl is best avoided by

landing in an open place some distance from bluffs and large obstructions, or, if the obstruction is a hill, on top of the hill itself. If, however, a landing to one side is necessary, and the aviator has a choice of sides, other things equal, he should take the *windward* and not the *lee* side. Finally, if a landing close to the lee side is compulsory, he should if possible head up the hill with *sufficient velocity* to offset any probable loss of support due to an eddy current in the same direction. He could, of course, avoid loss of velocity with reference to the air, and therefore loss of support, by heading along the hill, that is, along the axis of the vortex, but this gain would be at the expense of the dangers incident to landing in a side or cross wind. His only other alternative, heading down the hill, might be correct so far as the direction of the surface wind is concerned, but it probably would entail a long run on the ground and its consequent dangers.

"Eddies of a very different type, relatively small and so turbulent as to have no well-defined axis of rotation, are formed, as is well known, by the flow of strong winds past the side or corner of a building, steep cliff, and the like. In reality such disturbances are, perhaps, more of the 'breaker' type, presently to be explained, than like a smoothly flowing vortex, and should be avoided whenever the wind is above a light breeze.

"Clearly, the support to an aeroplane flying either with or against a wind of this kind is correspondingly erratic, and may vary between such wide limits that the aviator will find himself in a veritable nest of 'holes' out of which it is difficult to rise, at least with a slow machine, and sometimes dangerous to try. However, as the turmoil due to the horizontal winds rapidly decreases with increase in elevation, and as the aviator's safety depends upon steady conditions, or upon the velocity of his machine with reference to the atmosphere and not with reference to the ground, it is obvious that the windier it is, the higher, in general, the minimum level at which he should fly." (**2**). Cf. Mr. Miller's account, pp. 525–526.

Effect of gusts.—Aside from the obvious effects of vertical currents, already discussed, the mere changes of velocity in a horizontal direction that accompany the passage of gusts tend to produce an up-and-down motion in an airplane flying with or against the wind. If the airplane is flying with the wind, any increase in the velocity of the wind will momentarily reduce the support of the airplane, thereby causing it to drop, while any decrease in velocity will momentarily increase the air speed of the machine, tending to make it rise. The reverse is the case if the machine is going against the wind.

This is because in a steady wind an airplane itself moves as if in a calm. Thus if the wind is unsteady the number of gusts encountered in a given time will be the same whether there is a following or a head wind. And if, as the anemometers indicate, gusts have no more abrupt onset than end, the effect of a gust from in front or of a lull from behind should be the same. Nevertheless, aviators say they can feel the difference between a head wind and a following one, and that they climb fastest against the wind. Soaring birds have the same experience. This would seem difficult to explain in any other way than that gusts begin more suddenly than they end. Apparently, we need more refined observation to show what the difference is.—*Abstract from C. C. Turner, Aeron. Journ., (London)* **22:** *285–6, 1918.*

Effect of gustiness on a turning airplane.—Probably the chief disturbance due to gusty wind—excessive tipping and side slipping—occurs not during straightaway flying but as the aviator turns at low levels from flying against the gusts to flying with them. For example, on April 3, 1919, Lieut. Col. F. T. Dickman and Maj. J. W. Butts, were killed in such a disturbance near Americus, Ga.

The two officers * * * had made the last turn of the field preparatory to landing. From the ground it appeared that Maj. Butts attempted to turn. The wind was coming in gusts and apparently caught the airplane with full force in such a way as to lift the tail vertically into the air. The usual nose dive followed the jerking of the plane into a vertical position, and it crashed to the earth.—*Washington Post, April 4, 1919.*

"Such an accident may be, and presumably is, caused as follows: The aviator starts turning, suppose, while in and facing a relatively slow-moving portion of the air. On banking, the plane is tipped with its underside more or less against the wind, whereupon the higher wing often runs into, or for brief intervals is caught by a much swifter current than that into which the lower still dips. Numerical values are not at hand, but the phenomenon of overrunning gusts is familar from the action of winds on isolated tall trees. This obviously increases the tip, and, in extreme cases, sufficiently to induce a dangerous side-slip.

"On the other hand, when turning from flying with to flying against the wind the high wing catches the increased impact on its upper side, and therefore in this case the result is merely a temporary decrease of the tip—an entirely harmless effect. Gusts that envelop the whole of an airplane while turning obviously affect the lift to some extent, even when the path of the wind is at right angles to the course of the plane, but seldom sufficiently to be of much importance." (**2**)

WINDS OF THE FREE AIR: TURBULENT WIND BOUNDARIES.

The difficulties of the pilot do not cease once he has risen above the turbulence of the lower air produced either by local convectional currents or by the tumbling of the wind over the surface of the earth. For example:

Mr. J. C. Edgerton, flying the mail plane between Washington and Philadelphia, July 4, 1918, rose above the surface bumpiness into much cooler air at 5,000 or 6,000 feet and had smooth flying until from 9,100 to 11,300 feet he experienced up and down currents, some of them strong. The logs of his mail flights are full of similar instances of bumpy layers at various elevations. On June 1, 1918, the air was bumpy between 2,500 and 4,000 feet and again from 5,500 to 6,500 feet between Washington and Baltimore, and between 7,000 and 8,000 feet near Philadelphia. On descending, the air was especially bumpy at 200 feet. Returning in the afternoon, heavy clouds had formed to a height of 10,000 feet, and vertical movements extended up to this height. In the vicinity of rain squalls the air was extremely bumpy and "sharp cross currents threw me off my course repeatedly." On descending, it was increasingly bumpy down to 2,000 feet. Aloft, a cold west wind overrunning a southwest surface wind, was evidently responsible for the convectional currents which made the clouds and rain and the bumpy condition of the air, first in two zones of moderate thickness and later throughout the lower 10,000 feet of the atmosphere, at least.

Rohlfs on his recent record-breaking altitude flight to 34,610 feet, September 18, 1919, said that even "at 31,000 feet, my machine hit a pocket and dropped 600 feet. It rocked from side to side, a terrible sensation.—*From newspaper account, September 19, 1919.*

Referring again to the flight of Capt. Bartlett, we find this newspaper statement:

Waiting here [Waco, Tex.] for the storm to pass, he took off again under black clouds which hung as low as 600 feet and with a strong south wind along the ground. He climbed to 3,000 feet and there found clear air and a brisk north wind.

There are numerous accounts by aviators which tell of wind boundaries which are entirely invisible. Says one:

Near the surface the air was comparatively calm, but when about 800 feet was reached the machine was noticed to pitch slightly, just as a vessel might do in a sea with a slight swell. These conditions con-

tinued until about 1,000 feet. On another occasion, when the ground temperature was 34°F., following a severe frost, somewhat similar conditions prevailed. Near the surface absolute calm prevailed until nearly noon; but at 800 to 1,000 feet a long, uniform "swell" was encountered, the "waves" being probably 50 feet in depth, over which the machine rode gracefully and smoothly. *Lieut. S. W. Addison.* (1)

"Ordinarily there is not more than 100 feet of turbulence on wind boundaries. The boundary separating two winds is easily noted by the great disturbance, and bumpiness, the violence of which depends on the velocity of the winds. In many instances the change of winds will be just above where the cloud layer is forming or slightly above the haze."—*E. M. Powers.*

"*Wind layers.*—For one reason or another it often happens that adjacent layers of air differ abruptly from each other in temperature, humidity, and density, and therefore, as explained by Helmholtz, may and often do glide over each other in much the same manner that air flows over water, and with the same general wave-producing effect. These air waves are seen only when the humidity at the interface is such that the slight difference in temperature between the crests and the troughs is sufficient to keep the one cloud capped and the other free from condensation. In short, the humidity condition must be just right. Clearly, then, though such clouds often occur in beautiful parallel rows, adjacent wind strata of different velocities and their consequent air billows must be of far more frequent occurrence.

"This fact is abundantly proved by all types of aerological work, as well as by all those who ascend into the air. Kite balloons in ascending are often seen to rotate, pointing their noses in various directions, indicative of various wind directions at different levels, yet there may be no cloud layer at the interface to mark it. Free balloonists make use of these layers of air, which may have different directions and speeds, in order to aid them in achieving whatever result they seek, such as distance or a given destination." (**2**)

"*Wind billows.*—When one layer of air runs over another of different density billows are set up between them, as is often shown by windrow clouds. However, the warning clouds are comparatively seldom present, and therefore even the cautious aviator may, with no evidence of danger before him, take the very level of the air billows themselves, and before getting safely above or below them encounter one or more sudden changes in wind direction and velocity due, in part, to the eddy-like or rolling motion within the waves, with chances in each case of being deprived of a portion of the requisite sustaining force. There may be perfect safety in either layer, but, unless headed just right, there necessarily is some risk in going from one to the other. Hence, flying at the billow level, since it would necessitate frequent transitions of this nature, should be avoided.

"When the billows are within 300 meters [1000 ft.], say, of the earth (often the case during winter owing to the prevalence then of cold surface air with warmer air above) they are apt to be very turbulent, just as, and for much the same reason that, waves in shallow water are turbulent. For this reason, presumably, winter flying sometimes is surprisingly rough. Fortunately, however, it is easy to determine by the aid of a suitable station barograph whether or not billows are prevalent in the low atmosphere since they produce frequent (5 to 12 per hour roughly) pressure changes, usually of 0.1 mm. to 0.3 mm. at the surface." (**2**).

CLOUDS AND RAIN.

Flying in clouds or above them is the choice of the aviator over enemy territory more than over friendly country. How the aviator in the United States feels toward the clouds is well shown by the classification of the weather conditions under which the postal aviators between Washington and New York have to fly (Aerial Age Weekly, July 8, 1918, pp. 816–817). In succession these are—ideal, fair, occasional clouds, frequent clouds, high winds, thick clouds, thick clouds and high winds, rain storms, combination of storms and heavy fogs. Clouds are generally avoided because one can not see where he is going nor keep right side up. Cumulus clouds, particularly those with hard-looking outlines, are avoided because of their bumpiness, coldness, and fogginess; also, not infrequently because they have falling rain. (Fig. 3.) Such clouds are usually roughest and wettest at their bases. An aviator at Wichita Falls, Tex., on approaching a large cumulus cloud rose to fly over it; but it "towered to the sky," so he flew through. Once inside, he said the cloud was so dense that he could not see the tail of the airplane, and that it required all his flying ability to keep his direction. A full account of "Danger in flying through clouds," by Capt. B. C. Huchs, was presented to the Aeronautical Society of Great Britain, and reprinted in Scientific American Supplement, June 15, 1918, page 375.

Strato-cumulus clouds and cumulus clouds with fuzzy edges have weaker ascensional currents and are less bumpy to fly through. (Figs. 4 and 5.) Aviators in flying about such cumulus clouds can easily lop off corners and even make small clouds evaporate by flying through them. Some cumuli have cavities 1,000 feet high in their bases. On one of the hottest Texas days, an aviator had some trouble with an overheated engine, so he flew in the disconnected patches of strato-cumulus clouds at 10,000 feet. These clouds were cool and smooth. They marked, nevertheless, the tops of convectional currents, which were prevented from going higher, apparently because of an inversion of temperature at that level. On descending, the avaitor had considerable difficulty with bumps in the lowest 500 feet. Strato-cumulus clouds which grow out of stratus on summer mornings are not particularly bumpy. At least, aviators in speaking of flights up or down through them have mentioned only the beauty of the tops or the vertical thickness of the cloud. Fogs and stratus clouds are real blinders for the aviators although the use of radio-directional apparatus is reducing the danger of getting lost.[1] In the Houston region, the stratus are often so low that flying below them is not attempted for fear of tress. An aviator above low stratus clouds, or over a fog is in a very difficult situation if he needs to land.

An occurrence at Love Field early in September, 1918, makes a good example. While 60 aviators were in the air, low-lying clouds suddenly appeared and gave a drizzling rain at 10 a. m. Before it cleared away, 21 of them had to come down in wet fields, and two airplanes were demolished because the pilots could not see to select their landing places. One lit in a pond and the other in a tree.

Flying in the rain is avoided, if possible. Even in midsummer in Texas, at 7,000 feet in the air, an aviator flying through a rain cloud felt so cold that he described the rain drops as "ice particles." The impact of rain drops is sufficient to make them feel solid. On this occasion, there was a considerable collection of water on the airplane. The weight of rain water can hardly affect the performance of the airplane much, unless the drops freeze on. In the spring of 1918 an aviator in Texas had such an experience during a shower; he flew up into a

[1] Cf. Wireless navigation for aircraft, *Nature* (London), Sept. 11, 1919, pp. 24–27.

cloud until at 7,000 feet his airplane had become so covered with ice that he could go no higher. The effect of rain on the propellor is destructive. The propeller moves at such a high velocity that unless specially protected the rain drops cut it as if they were bullets.

Airmen are unanimous in regard to the danger and unpleasantness of flying through rain and fog. To quote from the Scientific American, July 13, 1918, page 26, on "The Fog Problem in Aviation":

It is hardly an exaggeration to say that at the present time the only serious outstanding meteorological problem of the aviator is fog.

There is no means [except radio] of keeping one's bearings when flying in or over a fog, and the same is, of course, true of low-lying clouds. The compass tells which way the machine is pointing at any moment, but not the direction in which it is flying, except when traveling exactly with or against the wind. There are no landmarks in the air. Even more serious is the problem of landing in a fog. The chances are always considerable of striking dangerous obstacles, such as trees, buildings, or telegraph wires, or of alighting in bodies of water, swamps, etc.

Moreover, as one veteran flyer has stated: "What is distressing to the airman in fog is the impossibility of knowing whether he be slightly climbing or slightly descending, with the result that he may find himself charging full-tilt into hills, trees, or houses without time to save the situation."

In the recent air race from New York to San Francisco, Lieut. Edward V. Wales was killed by driving his plane into Elk Mountain, Wyo., during a blinding snow storm.

Aside from the general unpleasantness of flying in rain, the water may cause faulty engine action by getting into the carburetor and the ignition system. As to general turbulence within clouds, there is very little definite information from aviators because the propeller so violently churns up the air in the neighborhood, and this mixing is often sufficient to mask any real small-scale turbulence that may exist there.

THUNDERSTORMS.

In thunderstorms, however, these turbulent conditions are of considerably greater magnitude, and are, in fact, so violent that great danger is entailed in flying in or about them. Indeed, few aviators have flown into a thunderstorm and come out alive.

Experiences.—Lightning is one danger. About August 1, 1918, an aviator flew into a thunderstorm at Paxton, Ill., and was found dead, with lightning burns on his body. Another aviator a year earlier, thinking apparently that the thunderstorm was going with the lower wind flew into the storm and was killed. Several years ago a flyer named Ehrmann had his machine set on fire by lightning, but he escaped unhurt.—C. C. Turner, "The Romance of Aeronautics," page 229, *Philadelphia, 1912*.

Capt. Cave (**12**) says:

It is possible that the actual danger from lightning to an aeroplane flying through a thunderstorm may be no more than that incurred by a pedestrian walking across an open common during a storm. A pilot who was flying above a thunderstorm last summer reported that long sparks were given off by this machine at intervals. It is very likely that this happened every time there was a flash of lightning from the cloud below him.

Aviators in the United States have also experienced such discharges while flying in thunderstorms or through gaps between thunderheads.

The *turbulence* within a thunderstorm is awful to experience.

A French machine was called upon to ascend during a violent thunder and windstorm for important observation work over the German lines. When at a height of several thousand feet the members of the squadron below saw the turret and its machine gun stripped from the craft by the gale.

The observer's seat was next to go, but the occupant, grasping the wing stays, clung to the sailing plane. The craft was whipped about in the sky at will and the cloth completely stripped from the fuselage. Both pilot and observer were clinging to their broken craft when it reached earth after a series of gyrations rivaling the most daring acrobatics practiced by the Allied aces. Both occupants escaped serious injury.[1]

It is quite likely that in such cases pilots and observers think very little of thunderstorm structure or the meteorological aspects of the situation. An aviator told this story of a friend's experience:

Lieut. Dunn got into a thunderstorm once. There was lightning all around him; but it was pitch black otherwise. He jerked all the controls and the ship apparently did not respond. He went up and down and was helpless. He was certain he would be killed. One minute he would think he was O. K. and the next minute he thought he was on his back.

Another aviator, Lieut. Vance, says:

I was once caught in an approaching thunderstorm. I noticed that I was gaining altitude very rapidly, so nosed the plane down, but could not lose any altitude until I had gained up to 4,000 feet. I was in the clouds most of the time. I just kept the nose down, and finally came down; then I commenced to settle, and could gain no altitude even at the maximum climb.

Again:

Capt. Bartlett was caught in a severe storm over Arkadelphia, Ark., and held in that situation for 35 minutes. "His plane settled from an altitude of 6,000 feet to 3,000 feet and drifted about two miles sideways, when he finally broke through the storm and came out miles off his course but in dry weather." [2]

Lieut. F. Davis is reported to have fallen to within 300 feet of the ground in trying to fly through a thunderstorm near Memphis, Tenn.

"An Australian aviator, Lieut. H. W. Ellis, reports that he ran into an isolated storm cloud and received two downward bumps, caused by descending currents. These bumps were very severe, and the speed gauge registered well over 90 miles per hour." (**1**) Also he states that "on one occasion (about September, 1915), a machine got into a black or thunder cloud, and was turned completely round, at the same time receiving a downward bump."

As an example of the dangers encountered in the vicinity of thunderstorms, the following is quoted from the account of Lieut. G. S. Mason, U. S. N.:

On July 23, 1919, near Pensacola, Fla., machine No. 2474 was in horizontal flight approaching a squall on the right. As we passed a small black-fringed cloud, at about 1,500 feet altitude, I felt bumps affecting the plane emanating from the cloud. I started to glide lower, thinking to avoid these apparently local bumps, when the plane suddenly nose dived, so suddenly, in fact, that the gasoline was thrown out of the venthole in the carburetor, flooding everything and stalling the motor. I was thrown up under the yoke of the controls and for some little time was unable to recover my seat, although I pushed up hard to force myself down. The machine was then in vertical nose dive, with no pressure on the flippers. I kept the flippers neutral, realizing that when I obtained pressure on them it would be sudden and very possibly collapse the wings. Trying the flippers occasionally, I finally got them to take hold after losing between six and eight hundred feet altitude.

An aviator related that one evening in the vicinity of San Antonio, Tex., local thunderstorms forced a landing, and that later the flying was the bumpiest he ever experienced. He said there was a thunderstorm every 3 or 4 miles. Lieut. Weddington reported:

I experienced rough riding between Wichita Falls and Gainesville, Tex. My ship was tossed up and down like a leaf, falling as low as 500 feet and rising suddenly to 2,500 or 3,000 feet.

Lieut. E. M. Powers wrote:

I have found that flying just in front of a thunderstorm is the most trying experience an aviator can have. The bumps are very violent and rapid, though they are usually not very deep, 200 feet being the greatest. Sometimes the ship will fall with such rapidity that the water will spurt from the vent in the radiator cap and I have even had the gasoline spurt out. However, it has been my experience that when the heavy rain is encountered the bumpiness decreases. On one occa-

[1] W. S. Forrest, New York Tribune report, July 14, 1918.
[2] From newspaper account October, 1918.

sion, June, 1918, I flew just in front of a good-sized storm. It was the only cloud, with the exception of a few white ones that were small, in the sky. The wind started to blow and the clouds were rolling one over the other when I started across the face of the storm. My altimeter said 2,800 feet and the clouds were approximately 1,000 feet above me. It finally got so rough that I came down to 1,500 feet and found that the air was lots more smooth. Later I passed just to the rear of the storm, through some of the rain, and found that the air was perfecty quiet and remained so until I passed from over the dampened area, when I ran into the usual hot-day bumpiness.

Many aviators have experienced the great up-current which occurs on the front of the squall wind issuing from the base of a thunderstorm. Ascents of several thousand feet have been reported not only in Texas but also in Florida. Two of the most striking ones, both from Texas, will be cited. On one occasion, near Fort Worth, the aviators began to return to Carruthers Field on the approach of a thunderstorm. Lieut. Morgan on banking for a turn while just over the squall front was suddenly lifted from 2,000 to an elevation of 7,000 feet, a rise of 5,000 feet in almost no time. He thought that his altimeter had "gone crazy." On descending immediately he reached the field just before the squall struck it. Other aviators were lifted similarly by 2,000 to 4,000 feet. Those that landed after the "50-mile" squall began had to land with their propellers going full speed.

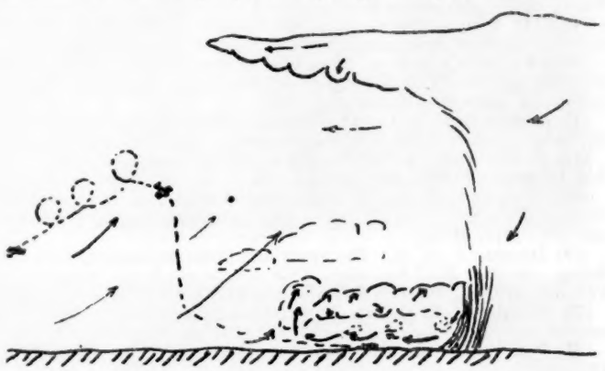

FIG. 10.—Winds experienced on thunderstorm front near Love Field, Tex., from description by Lieut. Cobb.

In the other instance, Lieut. Cobb was "stunting" near Love Field at about 3,500 feet altitude during the approach of a thunderstorm. After doing three evolutions, taking about 15 minutes, he found that he had gained some 3,500 feet in altitude, instead of losing 1,500 feet, as was usual. Sometimes the lifting would be of the order of 500 feet in a minute. This indicates that there was a wind with an average vertical component upward at about 5 miles per hour (2 m/s) blowing toward the storm, an upward rate quite to be expected under such circumstances. At the end, the aviators noticed sharp mammato-cumulus above and strato-cumulus clouds below them. They seemed to be at an altitude about midway between them, though they were some 5 miles away from the storm front. On descending they soon entered extremely bumpy air and were able to land only by diving into the wind with the engine on (Fig. 10). The rain began immediately after that. Landing in thunder squalls presents considerable difficulty. Once an aviator above such a squall, in the opposite return current, headed into the wind and made a descent to the field. He did not observe that the surface wind was opposite in direction. As he approached the landing place he noticed that for some reason he was not losing speed, and when only 5 feet from the ground saw that he was going with the wind. He was moving so fast that he went 4½ miles before getting sufficient elevation to turn and come back. Others have had similar experiences, though careful observation of dust, smoke, windmills or trees would show the surface wind direction. The main difficulty of landing in a squall wind seems to be due to its variable sustaining qualities, which nearly always make a smooth landing impossible. Very frequently, also, just as a landing is being made, or later, a gust will overturn the ship, even if the propeller is run at full speed.

Interpretations.—The air movements about thunderstorms, in the lower level at least, seem to be relatively simple. The heavy fall of rain and the coolness of the air under a thunderstorm produce a down-flow of air which spreads laterally in the form of a squall. The squall wind is stronger than the forward rate of advance, and so there is a considerable rate of ascent on the front; and the cold squall wedge also forces up the warm general wind. The air which goes down from a thunderstorm is supplied by a return flow of low velocity above the squall. (Fig. 10.) This return takes place above 1,000 or 2,000 feet and is probably strongest at 3,000 feet or higher. In the front of the squall the presence of obstructions will locally increase the rate of ascent of the air, especially when such obstructions are in the lee of a flat area. The extraordinary up-current near Fort Worth, referred to above, occurred just in the lee of Lake Worth. An airplane in the rain under the thunderstorm is likely to be carried down not only by the weight of the rain but also by the downflow of the air. An airplane in the squall itself is likely to be disturbed by eddies. An aviator who wants to go around a thunderstorm will find the fastest going at a height of about 2,000 feet, between the outflowing wind below and the inflowing one above.

AIR DENSITY CHANGES AS AFFECTING SUPPORT.

On cold days with high atmospheric pressure an airplane has little difficulty in "taking off." For example, Capt. H. H. Storrer (1) cites an instance when with the barometer at 30.67 inches and the temperature 30° F. "one could ascend at a fair rate with the elevators in the position usually employed in horizontal flights; this, of course, in calm air."

On hot days or at altitudes of a few thousand feet, on the contrary, the rarefied air often makes it difficult to rise from the ground. Aviators at Kelly Field, Tex., and Fort Sill, Okla., have noticed repeatedly that on very hot days there was difficulty in taking off, due to the rarefied air. More striking than this, however, is the case of failure of the propeller to "take hold" in the rare air of higher elevations. Lieut. Nutt, of Ellington Field, Tex., accustomed to the distance required to take off in low elevations, failed to take into account the fact that a greater distance would be required at a higher elevation, and at Denver, Colo., October, 1918, crashed into a fence in consequence.

Not only are these difficulties noticed in taking off, but also are they troublesome in landing, for the plane continues to roll along the ground for an unusual distance before coming to a stop. Landing fields at relatively high elevations should be larger than those near sea level and also at their edges should be free from obstructions like telephone and power lines, which might be permitted at lower levels.

ACKNOWLEDGMENTS.

Appreciative acknowledgments are due especially to the following Signal Corps meteorologists, formerly in

charge of aerological stations at flying fields, who did so much to collect information: P. W. Etkes, E. B. Scott, I. R. Tannehill, and P. S. Wagner. Also to the Post Office Department for placing at our disposal copies of Messrs. Edgerton's and Webb's mail-plane logs of the summer of 1918; to the Navy Department for accounts of some unusual experiences of naval aviators; and to Dr. Griffith Taylor, of Australia, who kindly forwarded copies of his material. Prof. W. J. Humphreys generously allowed extensive extracts from his revised manuscript, "Winds adverse to aviation," etc., to be used. The photographs were sent by Signal Corps meteorologists, R. D. Rusk, S. N. Gaines, and H. P. Parker. Mr. C. LeRoy Meisinger assisted in preparing the discussion.

CONCLUSION.

From the accounts of the numerous exciting experiences aviators have because of the conditions of the air, it is obvious that the more meteorology an aviator knows the better he can handle himself in the air, other things being equal. Furthermore, it is evident that the airplane has opened to the professional meteorologist a new and potent means of investigating the phenomena of the air. Much can be surmised from careful observations of cloud movements taken from the ground; but how much more satisfactory it is to be able to fly up and investigate, personally, what is happening!

The Weather Bureau would be glad to receive accounts of unusual flying experiences ascribable to weather or air conditions.

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FIG. 3.—Tops of large cumulus clouds.

FIG. 4.—Sunrise from airplane. (Notice two planes.) (Strato-cumulus.)

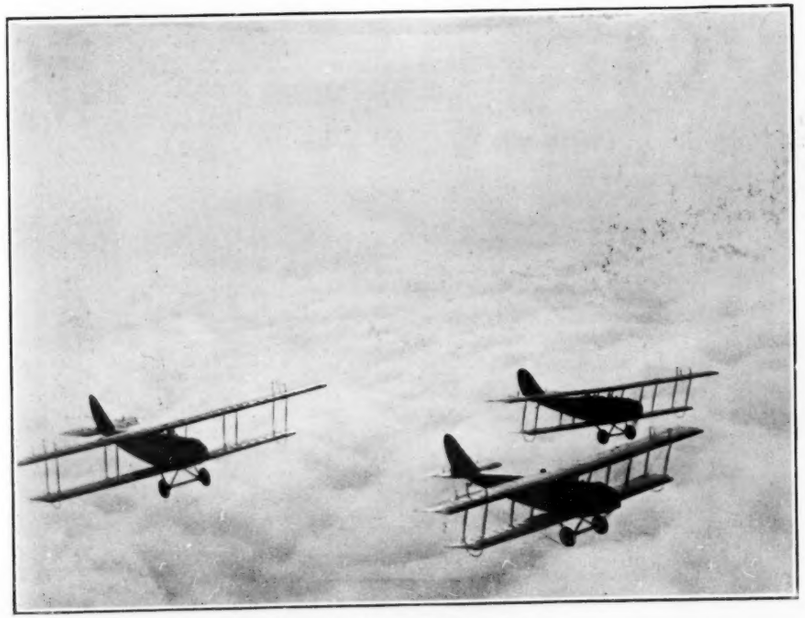
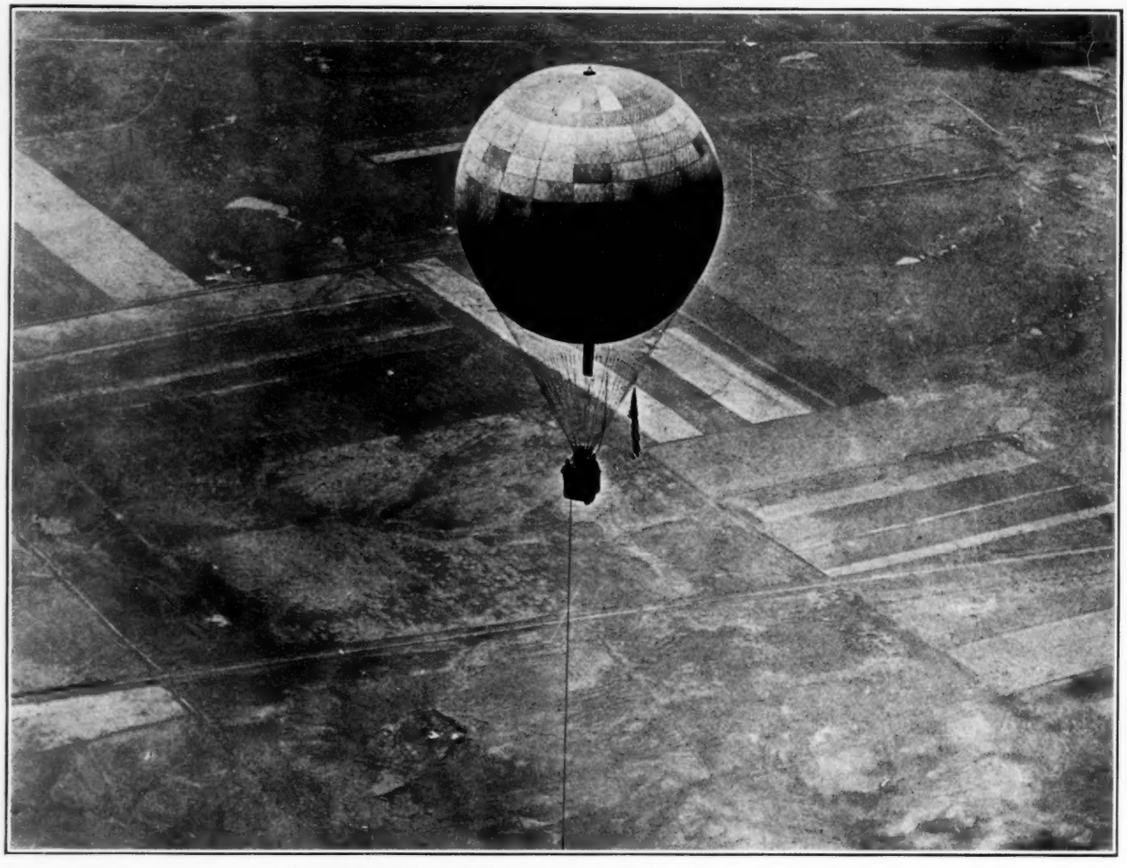


FIG. 5.—Thin layer of strato-cumulus.

FIG. 6.—Height about 5,900 feet. (Strato-cumulus.)

[To face p. 532.]

[To face p. 533.]



Free balloon in flight at altitude of 1 mile. (Photo taken from aeroplane.)

BALLOON RACE FROM FORT OMAHA THROUGH THUNDERSTORMS.

By C. LEROY MEISINGER.

[Dated: Weather Bureau, Washington, Sept. 8, 1919.]

One of the events in an aerial carnival held at Fort Omaha, Nebr. on July 13 was a balloon race. There were four entrants in the race—three balloons of 19,000 cubic feet capacity, and a larger one of 35,000 cubic feet, which was known as the judges' balloon. The day, however, had been intensely hot and uncomfortable, with a somewhat gusty southeast wind, which turned to south toward evening. About 3 in the afternoon, large cumulus clouds appeared in the northwest with a layer of alto-stratus which hung low along the northern horizon. Pilot-balloon runs, which were made at frequent intervals during the afternoon, constantly showed a strong southerly wind a few hundred meters above the surface. It was contemplated that the race should start about 4 o'clock, but the rather threatening aspect of the sky, the well known antipathy of balloonists for lightning, and the increasing gustiness of the surface wind, served to postpone the start until later in the evening.

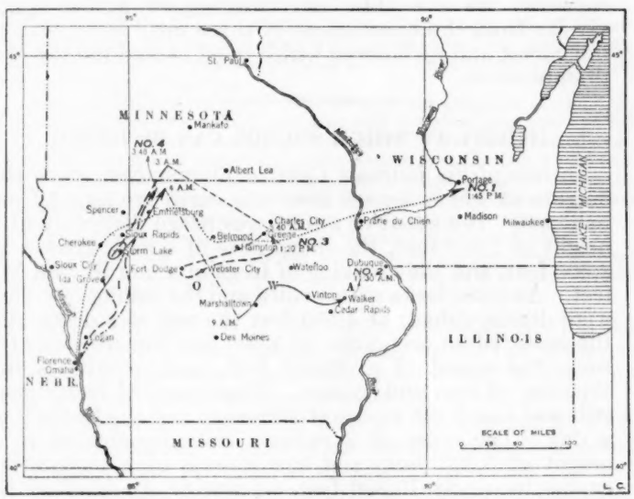


FIG. 1.—Paths of four balloons from Fort Omaha, Nebr.

About 5:30 came a sudden squall wind, which was generally interpreted to be the forerunner of a thunderstorm, for the alto-stratus had now spread around to the west so as almost to obscure the sinking sun. The squall, however, did not persist for over five minutes, and, at its conclusion, the surface wind became quite gentle. There was a slight drop in temperature. At 8 oclock, the weather having steadied somewhat, it was decided to begin the race, for there had assembled a crowd of spectators numbering several thousands. At 8:55 p. m. the first of the balloons rose slowly and gracefully from the field, followed at about three-minute intervals by the other three. The ground wind had practically died out by that time, so that the balloons, for the first 300 feet, rose almost vertically. Although the clouds persisted in the north, they had lost their threatening appearance, and it was conceded that the thunderstorm would not materialize. The more meteorologically inclined, however, looked dubiously at the low gray bank in the north toward which the balloons would undoubtedly be carried.

As the wind direction would indicate, there was a center of low pressure to the northwest, which was passing north of Omaha, and which was centered in southern Minnesota the next morning. As each balloon rose, it was caught suddenly in the more rapidly moving layer of air, and proceeded off to the north at a lively pace. The crowd disbanded after the getaway, and only a few watchers remained when the bags appeared as tiny specks in the cloud-enshrouded distance. For the crowd, the thrill was over; for the balloonists it was just beginning. The stories that were brought back to the fort by the returning balloonists seemed to indicate that they had all had their fill of ballooning in a storm.

In figure 1 are shown the paths of the four balloons, and even a cursory glance is sufficient to show how the gas bags were jostled about by the elements; to read the logs is to appreciate in some small measure the wildness of the ride.

Balloon No. 1, piloted by Lieut. Richard E. Thompson, with Lieut. James B. Jordan as aide, was the first to get away. It proceeded in a general north-northeasterly direction for the first six hours, after which it turned more easterly and began an ambling journey thorough northeastern Iowa. At 11 the following morning the Mississippi River was crossed just north of Prairie du Chien, Wis., and for the following two and three-quarters hours the balloon proceeded up the valley of the Wisconsin River. A landing was effected at that time, not so much because of immediate necessity, but because the experience of the preceding 16 hours had taught the travellers the true significance of an immense, dark, anvil-shaped cloud which seemed to be racing toward them from the south. Had it not been for this precautionary landing, there is little doubt that this balloon might have reached the shore of Lake Michigan.

The experiences of balloons 2 and 3, carrying Capt. A. C. McKinley, pilot; Lieut, James T. Neely, aide; and Lieut. W. E. Huffman, pilot, Lieut. W. E. Connolly, aide, respectively, are perhaps more striking because of the serpentine nature of their paths. Balloon No. 2 apparently encountered a whirl of several miles diameter in the vicinity of Storm Lake, Iowa, for their log shows that at midnight there were about 7 miles northeast of that place, and an hour later they were directly over the town, after which they proceeded in a northeasterly direction until they were lost in the clouds at 4 in the morning. For five hours they rode thus, uncertain as to their position and only occasionally getting glimpses of the countryside. When, finally, their position was determined they were about 20 miles southwest of Marshalltown, Iowa, a point considerably southeast of the place where they lost their way. They landed in eastern Iowa. Balloon No. 3, aftr leaving Omaha, pursued a general northeasterly course, but was also lost in the clouds in southern Minnesota. It, too, was carried southeasterly in the clouds and at 5:40 a. m. was traveling in a southwesterly direction over Greene, Iowa. An interesting loop was executed about the town of Fort Dodge, after which they journeyed back almost to Greene on a path parallel to that of their approach toward Fort Dodge.

Balloon No. 4, carrying Mr. A. Leo Stevens, pilot; Lieut. Col. Jacob W. S. Wuest, and Major M. J. O'Brien were forced to land at 3:48 a. m. They followed a northeasterly course, which was also quite irregular.

All the logs record passing through severe storms of thunder and lightning, rain, and wind. Balloon No. 1 apparently experienced the first of the storm at 11:15 p. m., although lightning had been visible for an hour and a half. Balloon No. 2 makes no mention of the storm until 3:30 a. m.; balloon No. 3 mentions rain at 2:40 a. m., and No. 4 entered the storm at about the same time. Some of the notes recorded by the aeronauts will serve to show briefly the very violent state of the atmosphere:

Balloon No. 1 at 11:25: "10 miles west of Ute. In terrific whirlwind. Very bad time. Basket straight out. Lightning close above and all around." and 15 minutes later, "Soaking wet and cold." At 2 a. m.: "Very bumpy wind; basket swaying; rain; lightning in all directions."

Balloon No. 2 at 3:30 a. m.: "In thunder and lightning storm; rain drove balloon down and drag-rope touched several times but basket did not. Decided to ride it out. Very high winds." At 8:30 a. m.: "Valving down before another approaching thunderstorm; will not land but ride it out low as before."

Balloon No. 3 at 3 a. m.: "In severe electrical storm; raining."

Balloon No. 4 at 2:45 a. m.: "Have entered thunderstorm; lightning on all sides." At 3:48 a. m.: "Landed. * * * Terrible rain and lightning."

Table of altitudes and directions.

Time.	Balloon No. 1		Balloon No. 2		Balloon No. 3		Balloon No. 4	
	Altitude (feet).	Moving toward.	Altitude (feet).	Moving toward.	Altitude (feet).	Moving toward.	Altitude (feet).	Moving toward.
10 p. m.	900	NNE.	2,450	NNE.	2,000	NE.	2,300	NNE.
11 p. m.	1,400	N.	2,100	NNE.	2,000	NE.	2,500	NE.
12 m.	1,800	N.	2,100	NNE.	1,500	NE.	2,650	NE.
1 a. m.	2,500	NNE.	3,000	NNE.	2,000	NE.	2,650	NE.
2 a. m.	2,700	NE.	3,300	NE.	2,000	NE.	3,300	NE.
3 a. m.	3,000	NE.	3,600	NNE.	6,000	NE.	3,800	N.
4 a. m.	1,300	NE.	3,800	(1)	6,000	(1)	.....	.....
5 a. m.	1,400	(1)	4,000	(1)	2,800	(1)	.....	.....
6 a. m.	5,000	S.	1,400	SSE.	3,100	SW.	.....	.....
7 a. m.	5,200	E.	1,800	SE.	1,800	SW.	.....	.....
8 a. m.	5,200	E.	4,300	E.	800	SW.	.....	.....
9 a. m.	6,800	NE.	1,700	ENE.	2,000	E.	.....	.....
10 a. m.	7,500	ENE.	7,150	E.	2,000	SE.	.....	.....
11 a. m.	4,500	E.	3,700	E.	2,200	NE.	.....	.....
12 m.	500	ENE.	.....	.....	800	N.	.....	.....
1 p. m.	9,000	ENE.	.....	.....	2,000	N.	.....	.....

[1] Balloons lost in clouds.

In order to discover, if possible, any uniformity in the changes of wind direction at various altitudes, the preceding table was compiled from the logs for each balloon for each hour of flight, showing the altitude of the balloon and the direction of the wind. It must be remembered that the direction of motion is often slightly in error, owing to the fact that it is determined only by the judgment of the observer; and if it happens, as it did in this case, that points of reference are not readily distinguishable, it is possible that the error might be very large.

Classifying the wind directions by altitudes and time, we find that the reason for the unfortunate conduct of the balloons is to be found in the fact that they were all affected by a wind shift line in the southern half of the cyclone. This line seemed to pass the balloons in the early morning, for up to that time all directions were, in general, toward the northeast—that is, a southwest wind. After that time the directions are, in general, toward the southeast or east—that is, a northwest or west wind. Of course, there are isolated discrepancies, but these are obviously due to local phenomena, such as whirlwinds or eddies, or to the personal equation of the observer.

While these flights were not made with any intention of being of scientific nature, nor even were there any hopes of records being established with balloons of so small capacity, we are able, nevertheless, to gather quite vividly from the experiences of these men the extent of the unrest and turbulence which must attend the life of a thunderstorm.

HEIGHT AT WHICH SOUNDS CAN BE HEARD.

In one of his journals Camille Flammarion gives the heights at which sounds from the earth are heard from balloons. The shout of a man was heard distinctly at a height of 1,600 feet, the sharp note of a mole-cricket at 2,500 feet, and the croaking of frogs in a morass at 3,000 feet. At 3,255 feet a man's voice and the rolling of a cart were distinguished; at 4,550 feet the roll of a drum and the music of an orchestra; at 5,000 feet the crowing of a cock, the sound of a church bell, and sometimes the shouting of men and women. Nine hundred feet higher still was heard the report of a musket and the barking of a dog. The noise of a railway tram penetrated to a height of 8,200 feet, and the whistle of a locomotive engine to nearly 10,000 feet.—*Scientific Amer., July 27, 1918, p. 63.*

THE CONSTANT-ELEVATION FREE-BALLOON FLIGHTS FROM FORT OMAHA.

By C. LEROY MEISINGER.

[Dated: Weather Bureau, Washington, Sept. 15, 1919.]

SYNOPSIS.—By means of two free-balloons from Fort Omaha, Nebr., sailing at constant elevations of 5,000 and 10,000 feet, respectively, it was possible to determine with fair accuracy the trajectory of an air particle in the given pressure distribution. The upper balloon was able to maintain its elevation much more satisfactorily than the lower, because of its comparative freedom from the effects of the Ozark Mountains. A comparison of the actual speeds of the balloons with the computed wind speed or gradient wind shows that the lower balloon, especially during the smoothness of the night, averaged within 0.5 meter per second of the computed speed. The paths of both balloons were practically the same, showing that the effect of the controlling cyclone, the center of which was over the Great Lakes, persisted to a considerable height. The speed of the upper balloon was slightly greater than that of the lower.

Purpose.—The idea which culminated in the free-balloon flights from Fort Omaha on April 16, 1919, came indirectly from W. J. Humphreys, professor of meteorology in the Weather Bureau. The following extract from a memorandum written by Mr. Willis Ray Gregg, meteorologist, Weather Bureau, will best explain the purpose and value of the enterprise:

* * * Although observations of temperature, etc., during a free-balloon flight would be interesting, their value is questionable because, of course, the balloon is moving with the wind and the instruments, therefore, receive but little ventilation. The following project would be well worth attempting:

Have the balloon reach and maintain a certain definite altitude, e. g., 2 kilometers above sea level, and drift with the wind for as long a period as possible. The observer should note carefully the places passed over, and make a report with a sketch of the route covered. This would enable us to determine the actual trajectory of a particle of air under the influence of a given pressure distribution. Shaw and Dines have done much theoretical work along this line and it would be extremely interesting and valuable to have data for checking their conclusions.

This suggestion is not original with me, it having been proposed recently by Prof. Humphreys during a conversation as to suitable lines along which the work of this division should be developed.

Thus, the purpose of the flights was to determine the trajectory of an air particle, acting under the influence of a given pressure distribution, with a view to checking theoretical considerations previously made.

Methods employed.—The plan, as worked out at Fort Omaha, consisted in sending out two free balloons of equal capacity—one to travel at an altitude of 5,000 feet and the other to maintain an altitude of 10,000 feet above sea level. Thus the purpose, as set forth above, would receive double consideration, and, in addition, would afford the advantage of simultaneous observations at different altitudes.

The story of the journey.—Before proceeding to the discussion of the meteorological aspects of the flights, I shall narrate briefly some of the experiences of the voyages. For convenience, the balloons were numbered 1 and 2, the lower being No. 1 and the higher No. 2. The lower balloon was manned by Lieut. Col. Jacob W. S. Wuest and Lieut. Ralph A. Reynolds; the higher, by Capt. Frank W. Goodale and myself. As to the experience of the lower balloon I will quote from an account written by Lieut. Reynolds:

"Our balloon was following the general course of the Missouri River and was slowly climbing to our prearranged altitude. The junction of the Platte and the Missouri was below us, and Plattsmouth was just ahead. We soon passed Nebraska City and Auburn, * * * and at 3:30 a. m. we were crossing the Kansas River at Lawrence. At 6:30 we crossed from Kansas into Missouri, and five minutes later the sun appeared on the horizon, beamingly confident that we would soon rise to a higher altitude. The green fields stretched away as far as the eye could see like a vast checkerboard. The mining region around Joplin and Carthage was visible, and one could make out the dim outlines of the foothills of the Ozark Mountains. Below us were lilac bushes in purple bloom and cherry trees proudly bore their white blossoms.

"Our trouble was about to begin. The cooling effect of the woods began to contract our gas and we began to drop.[1] Ballast was thrown and we ascended slowly until we reached a height where the mountain winds failed to affect the balloon, then the sun expanded the gas until we ascended far above our desired altitude. We valved down to this altitude and the mountain winds greeted us again. This process was repeated with varying success several times. Finally the ground wind became so strong that, as we would come down near the tops of the mountains, the cross currents would assume control of our balloon and take us wherever their slightest whims would dictate. This was not the most soothing thing for our nerves at this particular time; also we were running short of ballast. It was decided to go high enough to get above the effect of the mountain currents and remain there until we had passed the vicinity of the Ozarks. We attained an altitude of 13,000 feet, where we remained until we had chosen our landing field. The balloon was valved down to 7,000 feet, where we were caught in a warm, vaporous cloud. This sent the balloon up to 10,000 feet again, which was highly disturbing since we had only five bags of ballast (about 150 pounds) left. However, we began our descent and came down at the rate of 900 feet per minute to 4,000 feet. At this point we poured over our water, which checked us slightly. But as we neared the ground, the radiation of heat from the ground checked us completely at 300 feet.

"We made an uneventful landing at Cabot, Ark., at 2:35 p. m. Before many minutes had elapsed, many of the natives of the section were on the scene and giving us every assistance possible. Their genuine hospitality was most charming and was one of the most pleasant incidents of the whole journey."

Thus it seems somewhat of a paradox to speak of this as a constant-elevation flight; nevertheless, this irregularity occurred in the latter part of the journey only, for the altitudes maintained during the night were quite constant.

I will tell in somewhat greater detail of the trip in the upper balloon. The first balloon was led from the balloon house at 10:35, followed by the spectators. After a very little weighing off, and with no confusion, it slipped off into the moonlight. The crowd now turned back into the balloon house to see the getaway of the second. Our balloon was not filled to capacity, because of the fact that we were to ascend to the higher altitude, and there would naturally be a loss of gas through expansion. If we had had the full 35,000 cubic feet, however, we could have gotten away with more ballast; as it was, the situation was "pitiful," as one onlooker described, for bag after bag of sand and one of the water bottles had to be sacrificed before the balloon manifested any desire to rise. Finally we were dispatched into the night at 10:45. It was indeed impressive to us in the basket to see the uplifted hands waving to us, and the uplifted faces, illumined by the pale moon, and to hear the good-by calls growing fainter as we receded.

[1] There may have been a down-current as well.—C. F. B.

In an hour, we had touched the 10,000-foot mark, and had been carried down the valley of the Missouri, first in Iowa and then in Nebraska, due to the devious course of the river, until we were 10 miles northeast of Nebraska City. We were now permitted to realize the beauties of a night trip at high altitude. True, it was cold—the thermometer had dropped to 8° F.—but the beauty of the moonlit landscape, studded with cities, more than offset any trifling physical discomfort. First, of course, there was Omaha, with Council Bluffs across the river. The streets, the cars, the automobile lights, the blinking electric signs—each was doing its dazzling bit. As we withdrew from the city, we saw villages on every hand, some with only two or three street lights, but others more generously illuminated. So high were we that the lights of Lincoln, hazy in the horizon mist, could be discerned. Later, we passed near St. Joseph and Kansas City, which vied with Omaha in scintillating beauty. Above, the sky was clear, save for a few wisps of cirrus; the white moon rode in triumphant splendor, and a meteor slipped silently, fading in a vaporous mist.

About 5:30 the dawn began and the countryside seemed to change in character completely. The lights of towns began to fade, the colors of the fields began to assert themselves—where there had been shades in the moonlight, there now were tints. At 7 o'clock we crossed out of Missouri into Arkansas in a southeasterly direction.

Perhaps through sympathy with the proverbially slow train, the wind speed was noticeably less and we began to drift lazily along. The rising sun began to expand our gas and we showed a tendency to rise, although the effect was not too strong. After the altitude of 12,000 feet was attained, we valved back to 10,000. The Arkansas River was plainly seen to the southwest, while far in the southeast, in the glint of the morning sun, were seen bright spots in the haze, which were unmistakably bends in the Mississippi near Memphis.

As to exactly what we saw, I shall not attempt a description. The Ozarks are beautiful, the winding white roads threading themselves about the hills served to lead the eye from one hamlet to another, while the railroads pursued sweeping curves over trestles and through tunnels. The hills themselves were chiefly evident by the shadows they cast. Passing out of the mountains, we came in sight of Little Rock—near enough that we could see the white statehouse, and the bridges over the Arkansas River.

By this time we were getting over the Arkansas Valley east of Little Rock. The country seemed to be very swampy, and where the ground was bare it was apparently wet,—but where the pine forests spread along for miles we could see the water shining and reflecting the skylight among the trees. Over this forest area and swamp land a tendency to descend required an almost constant expenditure of ballast, of which we had none too much. We seemed to be drifting slower and slower, and now that we were approaching the Mississippi were aware that we were being pulled toward it. As far as the eye could reach, the serpentine Mississippi continued its amblings and more and more we seemed to come into its control.

Of all the hundreds of square miles within our view, there were only a very few which appeared to be cleared and under cultivation, and in which we might effect a landing. But, at this altitude, there was no other prospect than a wet landing in the river. In consequence, we threw some ballast and in a few minutes were sailing at 12,500 feet, and happily drifting across the river toward the east. We passed directly over the town of Greenville. On the river was a steamer, and to the right lay Greenville; a large cumulus cloud far below blotted out the town of Arkansas City. With so little ballast and so few available landing spots it was decided to land at once.

I must digress, for the moment, to mention the physiological and psychological effects of the long period at the high altitude. Capt. Goodale is not inherently belligerent, nor am I, but it did happen that for a time we entertained more or less hostile sentiments for one another. I do not mean that either of us sought to heave the other out of the basket, but we became mutually sullen for no cause at all. It was later explained by the physicians at the fort, as due to nothing less than the fatigue caused by a lack of the proper constituents in the atmosphere at that level. Indeed, we are informed that a small tube of oxygen would have acted as a literal elixir d'amour, and the captain and I can recommend its being carried as a great benefactor at high levels.

Our descent from the lofty altitude was quite rapid; for six minutes we fell at 1,000 feet per minute, which is decidedly too fast for comfort. Due to the rapidly changing barometric pressure, the desire is to hold one's mouth as widely open as possible to adjust the lungs to the new conditions. As we neared the ground we noted that the ground temperature was very high; moreover, the air was oppressively humid and stuffy. This warmth acting on the gas in the balloon served to expand it faster than it could escape through the valve, although the valve was held open continuously. Thus we dragged across the first field, unable to get down. We were approaching a railroad track with telegraph lines and trees beside it. These had to be jumped; consequently our attention was turned to getting ballast over. Our lunch was the nearest thing at hand, and there ensued a veritable rain of boiled eggs, oranges, and chicken sandwiches upon the plantation below. But they served their purpose, for we jumped the wires.

We were able to get down in the next field after having the bag, in deflating, parachute sidewise in the netting and drag us through muddy pools for about a quarter of a mile with the basket on its side. We were on a cotton plantation near Arcola, Miss., and of course were surrounded by a crowd of negroes, who were of the opinion that we had fallen unintentionally. They had been watching us, they said, for about an hour, and were quite amazed that we should precipitate ourselves voluntarily in their midst.

Now, the effect of the high altitude and our rapid descent asserted itself. The captain, to whom packing a balloon is almost a subconscious operation, went through the work in whirlwind fashion, while I was so mentally befogged that I had to think twice how to do the most ridiculously simple things. An overwhelming desire to sleep overcame me. As soon as the packing up was concluded, the captain complained of a splitting headache, and I could have toppled over in the mud for the sake of a little rest.

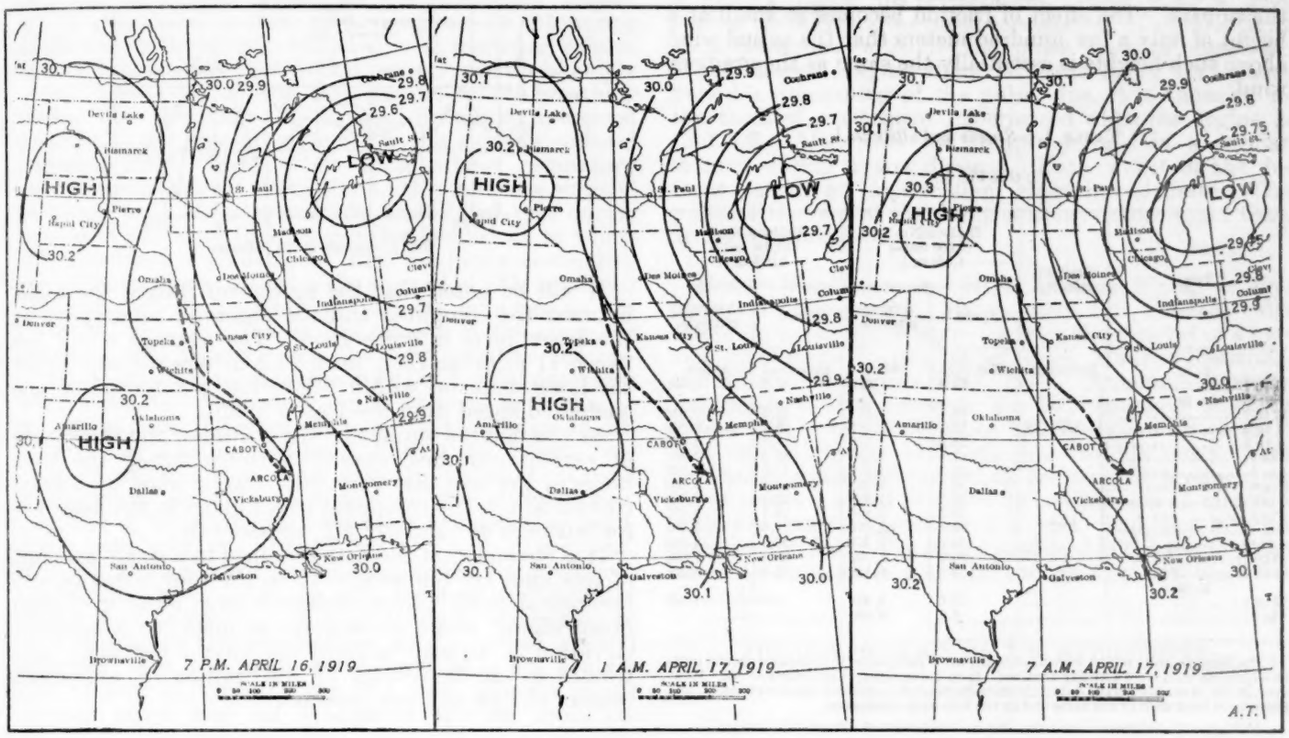
These are the salient features of the trip from a popular standpoint. It will now be of interest to discuss the trip from a more scientific standpoint.

Pressure distribution.—Figures 1a, 1b, and 1c represent sea-level pressures at 7 p. m., April 16; 1 a. m., and 7 a. m., April 17, 1919. Figure 1b is drawn for 1 a. m., April 17, and is interpolated from the maps of the pre-

ceding evening (1a) and the following morning (1c). The trend of the isobars is, in general, the same in all three maps.

On each of these charts is shown the path of the balloons. The solid part of the line indicates the portion traversed up to the time of the map, the dotted part shows the route taken after the time of the map.

Figure 2 is almost self-explanatory, since it represents the courses of the two balloons, as seen laterally. The topography is represented in solid black in cross section along the path. The cities and towns passed over are also indicated. The abscissae represent miles traveled, and the ordinates represent altitudes in feet. The hourly positions of the balloons in their paths are indicated.



FIGS. 1A, 1B, 1C.—Pressure distribution during the flights.

At Fort Omaha, all day previous to the flights, there was a steady NNW. wind. It was cloudy all day with a tendency to break up toward evening. It had been contemplated at first to start the flight about 6 p. m., but at that time the sky was still overcast, so that it was at once obvious and necessary that the flights be postponed, since a clear sky was imperative to the successful accomplishment of our purpose. There was a very rapid clearing at 9 p. m., which assured the trip, and at 10:33 and 10:45 p. m., respectively, the balloons took to the air.

It is seen from this chart that the first portion of the flights is most valuable for the purpose, since better equilibrium was obtained before the influence of the sun was felt. Another interesting fact is that both balloons followed practically the same course, the slight deviations of the lower one being due, without doubt, wholly to the effect of the currents about the Ozark Mountains, which were not experienced by the upper balloon. This emphasizes the point that the winds on the western or southwestern portion of a LOW seem to persist to great heights

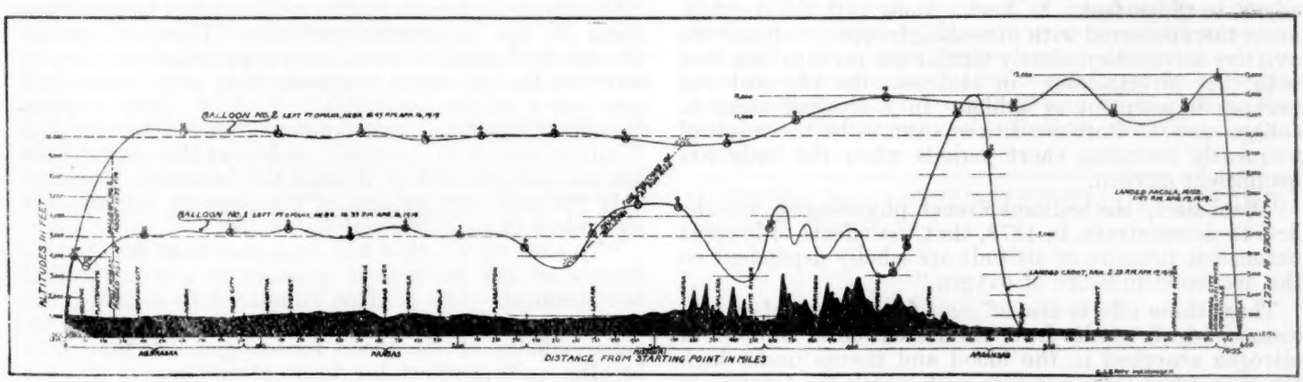


FIG. 2.—Lateral projection of balloon flights.

Gradient winds.—It is of interest to compare the actual directions and speed of the balloons with the theoretical "gradient wind," which is defined as the wind in which equilibrium is maintained between the pull of gravity down the pressure slope, the deflective tendency due to the earth's rotation, and centrifugal tendency due to the curvature of the wind path. The direction of the gradient wind is normal to the pressure gradient or parallel to the isobars. The effect of friction becomes so small at a height of only a few hundred meters that the actual wind above such heights is essentially the same as the gradient wind.

TABLE 1.—*Speeds and altitudes.*[1]

(See Fig. 3.)

Time.	Gradient velocity.	Balloon No. 1. (5,000 feet= 1,524 m.).		Balloon No. 2. (10,000 feet= 3,048 m.).	
		Speed.	Average altitude.	Speed.	Average altitude.
p. m.	*Meters/sec.*	*Meters/sec.*	*Meters.*	*Meters/sec.*	*Meters.*
11 to 12		13.4	1,371	23.2	2,591
a. m.					
12 to 1		19.7	1,554	21.5	3,048
1 to 2	14.8 (?)	13.4	1,580	19.2	3,048
2 to 3		14.3	1,570	14.8	3,048
3 to 4		12.5	1,585	12.5	3,017
4 to 5		12.5	1,575	17.0	3,050
5 to 6		14.3	1,493	17.0	3,050
6 to 7		15.2	1,220	22.8	2,895
7 to 8		10.3	1,828	16.1	3,078
8 to 9	11.5	8.9	2,073	21.0	3,505
9 to 10		20.6	1,371	29.3	3,566
10 to 11		26.8	1,402	22.4	3,658
11 to 12		3.6	1,158	17.0	3,353
p. m.					
12 to 1		11.6	2,438	8.0	3,353
1 to 2		6.7	3,353		

[1] The English units which were used in the early portions of this paper were the units in which the data were actually obtained—from barographs, thermometers, etc. However, in the discussion of the data, it is more convenient to employ the metric units, and these have been used in the table and in the following discussion.

Table 1 and figure 3 show the distances actually covered by each balloon, taken from figure 2, and the average altitude during each hour. The computed gradient wind is shown in the second column. It is computed from the isobars at 1 a. m. and 7 a. m.

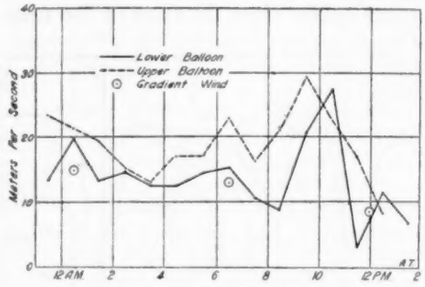


FIG. 3.—Speeds of the balloons.

It will be noted that the agreement during the night between the computed and the observed wind speed at the lower level is quite good. The average speed between 11 p. m. and 5 a. m. is 14.3 meters per second for the lower balloon, within 0.5 meters per second of the computed speed from the 1 a. m. map.

As was pointed out above, the altitudes, and the speeds at various altitudes, were so variable during the later hours of the trip that very little can be done by way of comparison. The computed winds given in the table are for latitudes 40° and 37° 30′, respectively.

It is obvious that the data obtained in a single attempt of this kind are too meager to be the foundation of any theoretical work. Nevertheless, a large number of such observations, where an attempt to maintain a constant elevation is strictly adhered to, would certainly contribute to our knowledge of the motion of air about centers of high and low pressure.

THE PHYSIOLOGY OF THE AVIATOR.[1]

By PROF. YANDELL HENDERSON.

(Abstracted from *Science*, May 9, 1919, pp. 432-441.)

The advantage which accrues to the aviator who is higher than his opponent has led to considerable flying at great altitudes. "Near the end of the war it was quite common for battle planes to ascend to altitudes of 15,000 to 18,000 feet. * * * Along with this development there occurred with increasing frequency among the aviators a condition closely similar to, perhaps identical with, the 'overtraining' or staleness, the physical and nervous impairment of athletes in a football team or college crew." Both conditions seem to be the result of frequently recurring short periods when the body has insufficient oxygen.

"Paul Bert,[2] the brilliant French physiologist, was the first to demonstrate, in 1878, that the effects of lowered barometric pressure or altitude are wholly dependent on the decreased pressure of oxygen."

Thus, these effects are different from those of caisson disease, which results from the formation of bubbles of nitrogen absorbed in the blood and tissues under high pressure, when "the pressure with which the tissues are in equilibrium should have been lowered considerably more than half its absolute amount in a few seconds."[3] Obviously, the aviator can not rise fast enough for this to occur. When the pressure is reduced the dissolved nitrogen diffuses rapidly into the air, and so the internal gas pressure becomes quickly adjusted to the external. "Nevertheless, the idea is still prevalent that hemorrhages occur in low barometric pressures. However, among thousands of people whom I had an opportunity to observe on Pikes Peak during a five weeks stay on the summit, I saw not a single nosebleed." * * * With oxygen breathing apparatus, two experimenters, "Schneider and Whitney, went into the steel chamber (at Mineola) and the air was pumped out of it until the barometer stood at only 180 mm., 23 per cent of the pressure outside—the equivalent of an altitude of 35,000 feet."

"To sum up all that has been said thus far, the influence of low barometric pressure is not mechanical but chemical. Life is often compared to a flame; but there are marked differences, depending upon the peculiar affinity of the blood for oxygen. A man may breathe quite comfortably in an atmosphere in which a candle is extinguished. The candle will burn with only slightly diminished brightness at an altitude at which a man collapses. The candle is affected by the proportions of oxygen and nitrogen. The living organism depends solely upon the absolute amount of oxygen—its so-called partial pressure."

[1] Presented before Harvey Society, Mar. 22, 1919.
[2] "*La Pression Barometrique*," Paris, 1878.
[3] Further details are given by Prof. Henderson and still more by J. S. Haldane, Nature, Vol. 96, pp. 173-174.—C. F. B.

The body may become acclimatized to a smaller amount of oxygen, but the acclimatization is generally too slow to be of much help to the aviator. "As we observed it in ourselves during our stay on Pikes' Peak acclimatization consists in three chief alterations: (1) Increased number of red corpuscles in the blood; (2) some change in the lungs or blood (Haldane considers it the secretion of oxygen inward by the pulmonary tissue), which aids the absorption of oxygen, and (3) a lowering of the CO_2 in the lungs is bound up with increased volume of breathing [and decreased alkaline reserve in the blood]."[4]

On Pikes Peak we saw that persons whose breathing under the stimulant of oxygen deficiency increased quickly to the amount normal for the altitude suffered correspondingly little, while those whose respiratory center was relatively insensitive to this influence suffered severely." It seems now firmly established that during any brief period of time, and under conditions to which the individual is accustomed, that the factor controlling the volume of air breathed is the amount of CO_2 produced in the tissues of the body through its influence on the C_H of the blood. "The oxygen tension of the air is the influence which determines just how sensitive the respiratory center is to excitement by CO_2.[5] The quickness with which the respiratory center changes with change in oxygen thus becomes an important criterion of fitness in aviator candidates. Fifteen to twenty per cent of all the men who pass an ordinary medical examination are unfit to ascend to the altitudes now required of every military aviator. On the other hand, these tests pick out a small group of 5 to 10 per cent, who, without apparent immediate physical deterioration, withstand oxygen deficiency corresponding to altitudes of 20,000 feet or more." It is particularly interesting to note that when the rebreathing test is pushed beyond the limit that the man can endure, be it the equivalent of only 10,000 or 25,000 feet, two different physiological types with all gradations between them are revealed. The fainting type collapses from circulatory failure and requires an hour or two to recover. Often the heart appears distinctly dilated. The other and better type, on the contrary, goes to the equivalent of a tremendous altitude on the rebreathing apparatus and loses consciousness, becoming glassy-eyed and more or less rigid, but without fainting. When normal air is administered such men quickly recover.—*C. F. B.*

The heart action of an aviator during flight has been summarized by Dr. G. Ferry (*Sci. Am.*, Apr. 29, 1916, p. 445) as based on a number of flights. His conclusions are: The pulse becomes more and more rapid from the ground up to a height of 750 meters; from this height up to 1,250 meters it still augments, but less rapidly; and above this height it again accelerates more rapidly. The period of slower acceleration seems to be explained by the fact that between 750 and 1,250 meters the air is usually calmer than at lower altitudes, and the wind more regular. Above this height the cold becomes a greater factor in acceleration. Each time a gust strikes the airplane the pulse accelerates. During a flight at a particular altitude the pulse remains constant. When descent begins there is again for a very short period a quickening of the pulse, due, it is thought, to the thrill of excitement experienced when the engine is shut off. After this the frequency falls in a regular manner during a slow descent. Each event in the descent causes an acceleration, short but definite. The pulse at the end of the flight is always more rapid than at the beginning.—*C. F. B.*

Henry Woodhouse in "High Altitude Flying in Exploration" (*Geogr. Rev.*, March, 1919, pp. 156-158) calls attention to the following notes from the account of a balloon flight made by Jacques Schneider, Maurice Bienaime, and Albert Senouique in May, 1913. Dynamometer tests were made at 10,081 meters: For Mr. Senouique on earth it was 105, in the air 110; for Mr. Bienaime on earth it was 140, in the air 155. At this altitude one's heart is beating about 110 pulsations per minute, producing a blood pressure equal to about 25 centimeters of mercury with the exterior pressure 210 mm. and the interior pressure 250 mm. The strain produced in the tissue of the circulation system is powerful enough to cause death.[6]—*C. L. M.*

THE COMPOSITION OF THE ATMOSPHERE.

By Dr. K. SCHÜTT.

[Reprinted from the Aeronautical Journal, London, November, 1918, p. 382.]

In the course of his paper Dr. K. Schütt refers to an investigation by A. Wigand, who took samples of air at various heights from 1,500 to 9,000 meters and established an increase in the proportion of hydrogen with increase of height and a decrease in the proportion of carbon dioxide. On the basis of this investigation, the following figures are given for the percentage of hydrogen in the atmosphere at 0.20, 50, and 100 km., 0.01, 0.05, 3.72 and 97.84. The subject discussed in greatest detail is the nature of the layer which acts as an electrical conductor and guides "wireless" waves round the globe. A proposal to determine the height of this layer by projecting electric waves obliquely upward and finding where they return to earth is mentioned.—*Bulletin Aero-Club Suisse," August, 1918.*

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[4] A fourth effect mentioned by Dr. A. M. Kellas, *Geogr. Journ., January, 1917*, in discussing the possibility of climbing Mt. Everest, is the more rapid circulation of the blood stream during exercise.—C. F. B.

[5] The aeronaut or aviator who may doze at high altitudes may experience the difficulties mentioned by Mrs. F. B. Workman, relative to sleeping at 21,300 feet in the Himalayas (*Independent, June 5, 1916, pp. 380–382*): "As soon as we began to doze and the respiratory movements diminished in force and frequency, the tissues did not get enough oxygen, and we would start up, gasping for breath."—C. F. B.

[6] A discussion of the cause and best means of fighting "flying sickness" is given by Lieut. Col. Martin Flack in "Flying Sickness," reprinted from *Aeronautics, in Sci. Am. Supp.*, Apr. 26, 1919, p. 262.—C. F. B.

HIGH LIGHTS OF AIR TRAVEL.

By M. LUCKIESH.

[Abstracted from Scientific American, Sept. 20, 1919, pp. 280, 292, 294.]

First of all, upon ascending, the passenger is impressed with the map-like appearance of the landscape. Country roads, sandy beaches, and other barren lands appear conspicuously bright, while the country itself is surprisingly dark, because of the large amount of shadow. The accompanying table of approximate reflection factors illustrates the general low reflection factors of the various earth and water areas:

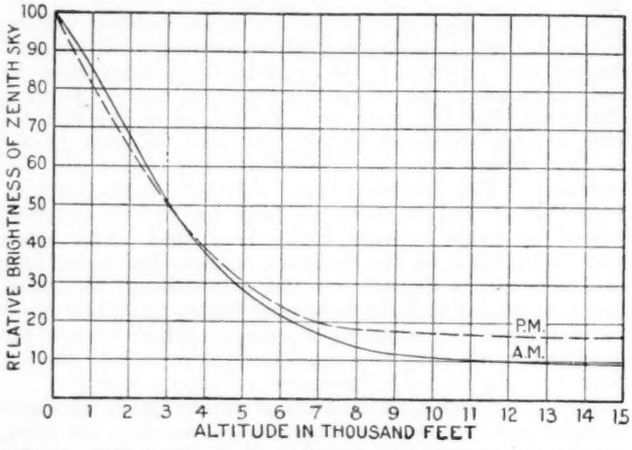
	Per cent.
Woods	3 to 5
Fields of grass and low-growing crops	5 to 10
Barren land (depending upon soil)	5 to 20
Inland water	5 to 10
Deep ocean water	3 to 5
Upper sunlit surface of dense clouds	70 to 80
Fresh deep snow	70 to 80
Compare:	
Perfectly white surface	100
Best white pigments	80 to 90
Black pigments	1 to 4
Black velvet	0.4

"Wet soil is darker than dry soil, owing to the moisture which fills the interstices. The refractive index of water is greater than that of air, with the result that there is less light reflected at the surface of the particle of soil bounded by water than when air replaces the water. The brightness of barren land obviously varies greatly with the kind of soil, but even for the same soil there is a considerable variation, depending upon the character of the surface. A freshly plowed field, even after it has dried, is much darker than after it has become smoothed by many rains. This is another example of the effect of shadows and light traps."

"Water varies in brightness and color, depending upon its depth and clarity. Very muddy streams in flood are exceptional cases and have the color and brightness of the soil. Ordinary inland waters, such as rivers, large lakes, and bays, are usually a dirty yellowish green in color, with a mean reflection factor of 7 per cent. Deep ocean water is a dark greenish blue and possesses a reflection factor of about 3 or 4 per cent. The brightness of water may be divided into two parts. One is due to the reflection of images of the sky and clouds, and this component of brightness obviously depends upon the *brightness* of the objects themselves and upon the angle of incidence of the light. The other component is due to light diffused within the water due to suspended matter and bubbles, and it depends upon the *intensity of illumination.*"

Cloud shadows are very conspicuous when seen from above, and quiet pools of water appear with almost inky blackness; in fact, they are often the darkest spots of the landscape. "This is easily explained. The water is perfectly clear and the bottom is black and porous. Little or no light is reflected except from the surface. Viewing a clear sky at perpendicular incidence, the brightness of the reflected image is only 2 per cent of the brightness of the sky. The sky contributes only a small part of the total light on a clear day and hence this 2 per cent of the brightness of the sky corresponds to but a fraction of 1 per cent of the brightness of a white surface receiving light from both the sun and sky. This accounts for the visibility of submerged objects, such as fish, mines, and submarines, and even the bottom itself if the water is not too deep, when these are viewed vertically downward ro nearly so."

The haze limit, which varies from 4,000 to 10,000 feet, is also one of the most beautiful effects of cloudland. The line is usually very sharply defined, and above it the sky possesses a purity of color such as is seldom seen from the earth's surface. Moreover, the heads of great cumuli reared through the haze like icebergs afford one of the remarkable sights in the air. "Clouds appear yellowish by contrast with this bluish or purplish haze and clouds floating in this tinted luminous ocean provide one of the beautiful effects of the aerial world. Sometimes there is an upper haze, apparently of [attenuated] clouds, but so thinly diffused and uniform that no cloud shapes are visible. Both of these hazes are chiefly responsible for the brightness of the sky, although the earth haze contributes the predominant portion of the sky brightness as seen from the earth's surface. If there were no particles in the atmosphere to be illuminated, that is, to diffuse light, the sky would be black or nearly so in the day time and stars would be visible. * * * At 20,000 feet the sky is sometimes very dark and measurements have shown that it contributes at this altitude as little as 4 per cent of the toal illumination on a horizontal surface at midday. The variation of sky brightness is illustrated by the two curves plotted from data obtained in the morning and in the afternoon on the same day. The points where the curves flatten indicate the top of the haze."



Relation of the sky brightness to altitude in morning and afternoon of a cloudless day.

"Of course, the haze reduces visibility, but it does not add much to the earth's brightness as seen from above because it reduces the earth's brightness by absorption as well as increasing it by reflection. From the standpoint of visibility the haze is generally more annoying to the observer at altitudes of about a mile than at very high altitudes because at the lower altitudes the observer in attempting to penetrate distance looks through a greater length of haze than is the case at high altitudes." The brightness of the upper surface of clouds is dependent upon their density or depth. When deep or dense they reflect light like great banks of snow or white pigments. The range of vision at high altitudes is also of interest. At a height of 4 miles on a clear cloudless day this range amounts to approximately 200 miles. "The extent of the range of vision is especially emphasized in viewing one of Nature's most wonderful spectacles—a storm—as only a single scene in a tremendous panorama."—*C. L. M.*

[To face p. 541.]

FIG. 1.—The *R. 34* approaching Roosevelt Field.

FIG. 2.—The *R. 34* landed (at dusk).

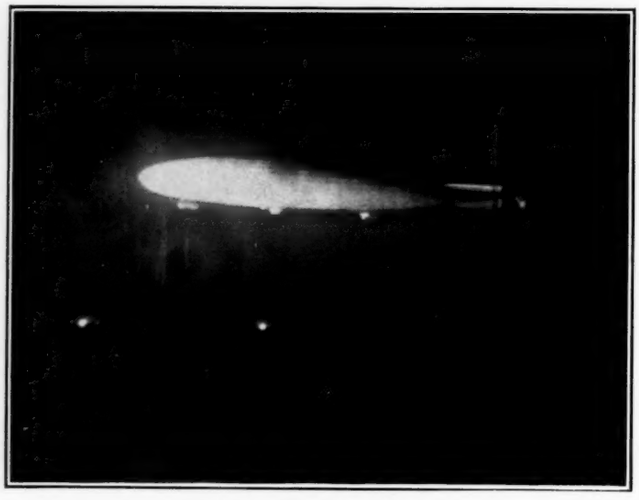


FIG. 3.—The *R. 34* at night.

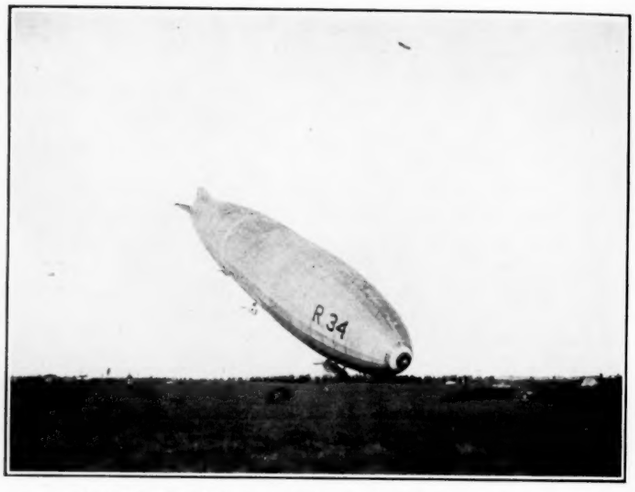


FIG. 4.—One of the difficulties of mooring an airship in the open. (See text, p. 542).

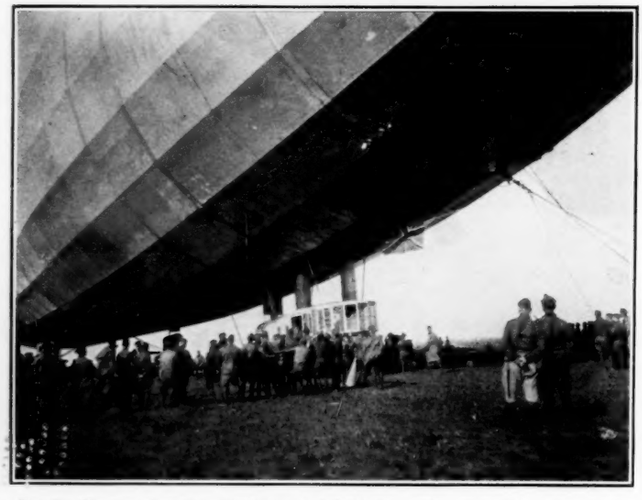


FIG. 5.—Close-up view of the *R. 34*, showing slight damage done as result of its position as shown in figure 4.

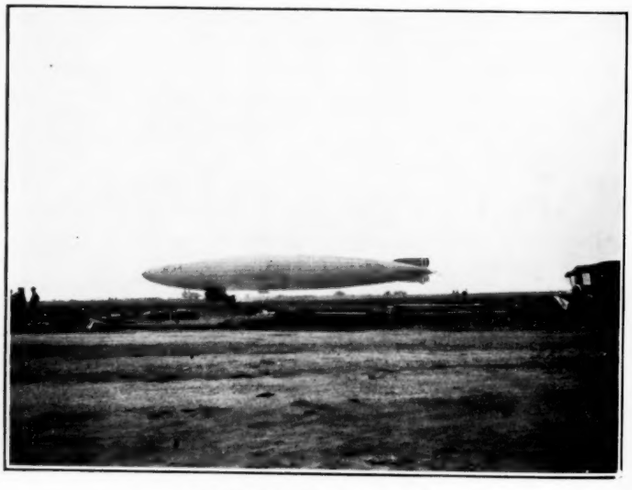


FIG. 6.—The *R. 34* at its moorings.

THE TRANS-ATLANTIC FLIGHT OF THE BRITISH DIRIGIBLE "R.34."

By WILLIS RAY GREGG, Meteorologist.

[Dated: Weather Bureau, Washington, Sept. 23, 1919.]

SYNOPSIS.—The British dirigible *R.34* flew from the British Isles to the United States in 108 hours and made the return trip in 75 hours, a good illustration of the influence of the prevailing westerlies in trans-Atlantic flight. During the first day of the westward trip northeasterly and easterly winds furnished some assistance, but thereafter cross winds or head winds were encountered most of the time. On the return trip southwesterly and westerly winds added considerably to the air-speed of the ship. Inasmuch as it was necessary to moor the ship in the open at Roosevelt Field, arrangements were made for the receipt and study of meteorological reports in order that warnings as to expected changes in weather conditions could be given to the officers in charge. The most difficult conditions to guard against were the sea breeze, thunderstorms, and alternate heating and cooling of the gas through the interruption of insolation by passing clouds.

The experiences of the NC crews, Hawker and Grieve, Alcock and Brown, and the *R.34* emphasize the necessity of wind assistance and the difficulties presented by the frequency of fog and clouds. The latter will cause less and less trouble as radio communication becomes better developed and more accurate.

event has been justly acclaimed as one of the most striking achievements of modern science in its resistless determination to overcome the seemingly antagonistic forces of nature.

The routes followed by the *R. 34* and the times required to traverse successive portions of those routes are shown in figure 7. Briefly, the record is as follows, times being given in G.M.T.: Left East Fortune, Scotland, 1:42 a. m., July 2; arrived Mineola, N. Y., 2 p. m., July 6; left Mineola 4 a. m., July 10; arrived Pulham, England, 6:56 a. m., July 13. The total distance covered was approximately the same for both routes, viz., about 3,200 miles. The time taken was a little more than 108 hours for the westward journey, and practically 75 hours for the eastward journey. No better illustration than this could be

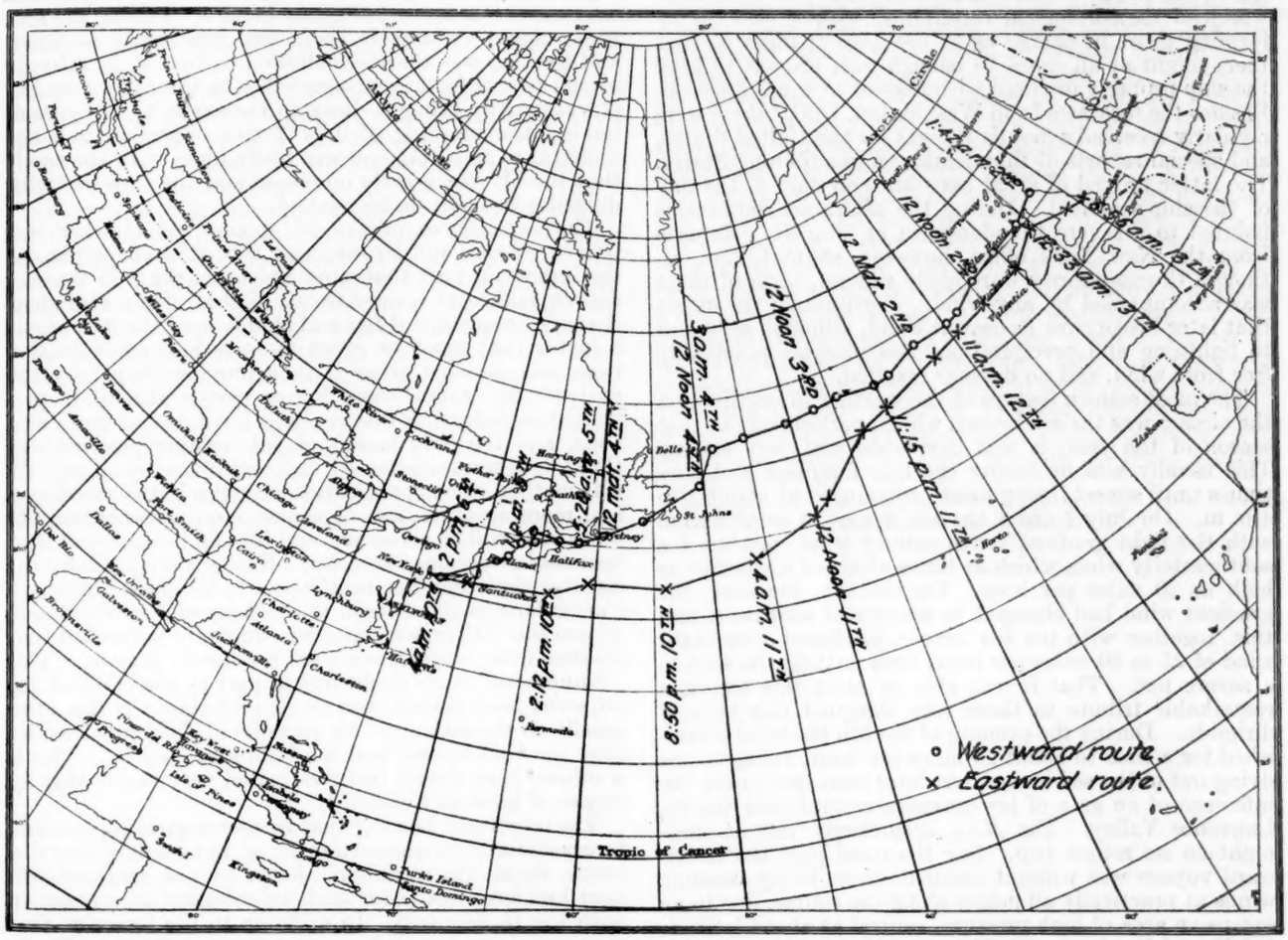


FIG. 7.—Routes followed by the *R. 34* in its trans-Atlantic flight.

As a fitting climax to the series of attempts to cross the Atlantic by air, the British dirigible *R.34* on July 13, 1919, successfully completed its memorable journey from the British Isles to the United States and return. Although third in the list of aircraft to cross the ocean, it was first of its type, lighter than air, to do so, and it was the first of any type to make the westward trip. The given of the influence of the prevailing westerlies in connection with trans-Atlantic flight. Not only was a longer time required for the trip to America, but a much larger amount of fuel was necessarily consumed. In the development of marine aviation on a commercial basis these factors will undoubtedly be given consideration in fixing passenger and freight rates for the two journeys.

Meteorological conditions during the flights are described in copious notes by Gen. E. M. Maitland, the official British observer on the *R.34*.[1] Pressure distribution and resulting winds are shown in Charts IX to XVII, inclusive, in the MONTHLY WEATHER REVIEW for July, 1919. During the first day, July 2, under the influence of an area of low-pressure central over southeastern England, northeasterly and easterly winds prevailed, thus materially increasing the airship's speed. Thereafter for the most part cross winds were encountered until Newfoundland was reached on July 4. The journey from this point to Mineola was extremely difficult owing to strong head winds as the result of a well-developed low over the St. Lawrence Valley. For a time practically no headway was made, but fortunately the eastward movement of the storm area brought northeasterly winds to New England early on July 6, and the airship reached Mineola with less than an hour's supply of fuel on board.

During its stay at Mineola the *R.34* was moored in the open, and it was necessary, therefore, to keep close watch of meteorological conditions, with a view to informing those in charge as to probable changes so that there might at all times be enough men present to keep the ship properly oriented with respect to wind direction. Besides the forecasts from Washington, D. C.,[2] there were regularly received synoptic reports for the United States, and special reports of thunderstorms in adjoining States. The latter proved of great assistance on July 6, the day of the ship's arrival. During the afternoon indications pointed to a severe thunderstorm at Mineola. Reports from the New York office, however, showed that, although thunderstorms were quite general, none of them was accompanied by any wind. Fortunately the storm that later broke over Roosevelt Field, although severe as to lightning and precipitation, was likewise practically free from wind, and no damage resulted.

The most serious feature of the weather in its effect on the airship was the sea breeze, which, particularly at that season of the year, is well developed and very strong. This usually sets in during the late forenoon and continues until sunset, being most pronounced at about 2 to 4 p. m. On July 7 and 8 the sea breeze, in combination with the light gradient northeasterly wind, produced a southeasterly wind, which at times attained a velocity as high as 20 miles per hour. On the 9th, however, the gradient wind had changed to south and southwest and this, together with the sea breeze, produced a resultant wind of 25 to 30 miles per hour, thus putting the ship to a severe test. That it was able to meet this test is a remarkable tribute to those who designed this type of dirigible. During the evening of the 9th the wind diminished for a time to about 20 miles per hour, owing to the dying out of the sea breeze, but later increased under the influence of an area of low-pressure central over the St. Lawrence Valley. The *R.34* accordingly left at midnight on its return trip. For the most part the homeward voyage was without incident, there being assisting winds at practically all points along the course, due to an extensive area of high pressure, central at about latitude 45° N. and longitude 25° W. (See Charts XIV to XVII, inclusive, July, 1919, MONTHLY WEATHER REVIEW.)

As was to be expected, a dirigible of the size of the *R.34* is much more easily controlled when it is in the air, its natural element, than when it is moored in the open. In the air it may run into ascending or descending currents and into winds of high velocity, but a skillful pilot can usually overcome these difficulties providing the ship is traveling at a sufficient height above the earth's surface. Descriptions of experiences of this kind are contained in Gen. Maitland's log, wherein he tells of severe bumps that were felt in or near thunderstorms over Newfoundland and New Brunswick, yet the airship was safely brought through them.

When moored in the open, an airship is not only subject to considerable strain because of sudden changes in the wind, but greater care is required in maintaining a proper balance between lift and ballast, for if, on the one hand, the lift becomes large the ship can be held down only with great difficulty; if, on the other hand, the lift is insufficient, the ship will settle to the earth and crush the gondolas. Naturally the most troublesome kind of weather in this connection is that characteristic of summer afternoons when insolation is at intervals intercepted by small patches of cumulus clouds. The sudden heating or cooling of the gas requires quick action in adjusting the dirigible's equilibrium. How serious this problem may become is shown in figures 4 and 5. During the first three nights at Mineola there was practically no wind, and the ship was therefore allowed to float at an altitude of 100 to 200 feet, as in figure 3. In the early morning it was usually brought down to the earth, as in figure 6, but on the morning of July 7 this operation was not undertaken until the sun was fairly high, with the result that the lift had greatly increased and the ship was with difficulty brought under control.

The experiences of the NC planes, of Hawker and Grieve, Alcock and Brown, and the *R.34* all emphazise the important part that wind assistance plays in the success or failure of trans-Atlantic flight. They also show that the frequency of fog and clouds over the Atlantic is a factor that must be given more serious consideration than was perhaps given it in a previous paper by the writer.[3] In several cases fog or clouds absolutely prevented astronomical observations for a day or more at a time, and the only means of determining position was through communication by radio with nearby ships. As this method of communication becomes better developed and more accurate, less dependance on astronomical observations will be necessary, and fogs and clouds will then become less serious obstacles. Rather unexpectedly the air over the ocean has been found to be quite "bumpy." Particularly is this true in the vicinity of Newfoundland, where the NC crews reported decidedly perturbed conditions, even when there were no clouds present. This "bumpiness" is no doubt due in part to the effect of the adjacent land masses, but in all probability is due principally to the mixing of air currents of different densities over the Gulf stream and the Labrador current. This is a subject that should be investigated very thoroughly by means of kites and balloons.

The important bearing that meteorological reports and forecasts have on trans-Atlantic, or, indeed, any long distance, flight was strikingly shown by the arrangements that had been made for such information in connection with the *R. 34's* trip, In addition to the forecasts that were regularly issued from the Weather Bureau, Washington, D. C., as to conditions over the North Atlantic, special reports were received and studied at Roosevelt Field by Lieut. C. N. Keyser and Mr. Samuel Gottlich of the Navy and by the writer of this paper, in order that the officers in charge might be kept constantly informed as to probable changes in local conditions, such as thun-

[1] See *Aeronautics*, July 10 and 17, 1919.
[2] See "Forecasts for the *R. 34*," by E. H. Bowie, MONTHLY WEATHER REVIEW, July, 1919, p. 505.
[3] Trans-Atlantic flight from the Meteorologist's Point of View. MONTHLY WEATHER REVIEW, February, 1919, 47: 65-67.

derstorms, high winds, etc. These special reports included observations every two hours with pilot balloons at Hazelhurst Field, under the direction of Lieut. Paul S. Wagner, Signal Corps meteorologist; and information as to the occurrence of thunderstorms in adjacent States. The pilot balloon records gave data of great value in predicting changes in the wind conditions both at the surface and at higher levels. During its flight the *R. 34* was furnished with European reports and with messages from ships at sea. These reports were studied by the airship's meteorological officer, Lieut. Guy Harris, R. A. F., who, in addition to advising Maj. Scott as to the best routes to follow, so as to avoid head winds, thunderstorms, etc., also kept a detailed record of the meteorological features of the flight, including some fine photographs of clouds and fog. It is sincerely to be hoped that Lieut. Harris will give us a complete history of the trip from the meteorologist's point of view.

THE GEOSTROPHIC (GRADIENT) WINDS OF THE NORTH ATLANTIC.

(Abstracted from back of Monthly Meteorological Chart of the North Atlantic July, 1919.)

Although surface winds cross the isobars at a slight angle, even at sea, the winds at only a small elevation blow essentially parallel to the isobars. Therefore, "geostrophic," or gradient, winds, parallel to the isobars are of interest to aviators.

The prevailing geostrophic winds have been worked up for three points—two in the Atlantic Ocean, namely, lat. 50° N., long. 40° W., and lat. 50° N., long. 25° W., and for the Valencia Observatory. The methods employed were to make use of weather maps for a 28-year period for the two Atlantic points and for a six-year period at the Valencia station. The results are summarized in diagrams which show the frequency distribution of the winds for the periods covered. For Valencia they are grouped by seasons, and for the two Atlantic points simply for the month of June.

Comparison of the three diagrams for the summer months shows considerable uniformity of conditions. In all cases there is a preponderance of west and southwest winds and those from the east are rare. In lat. 50° N. and long. 40° W., winds are well distributed around the compass, for the centers of deep cyclones occasionally pass south of that point. A more important detail is the high frequency of the northwest winds as compared with those of the two points farther east. The distinguishing feature of the summer diagram for Cahirciveen (Valencia) is the comparatively large proportion of northeast winds.

Taking the four diagrams for Cahriciveen together, we notice the high proportion of strong "geostrophic winds" in winter and also in autumn. The preponderance of southwest winds which is so marked a feature of the winter and spring diagrams disappears entirely in autumn. Northeast winds are found to be characteristic of autumn as well as spring.—*C. L. M.*

CLOUD FREQUENCIES WITH VARIOUS WINDS.*

The Meteorological Chart for the North Atlantic for August gives two interesting charts showing the frequencies of clouds with winds of various directions at Valencia and at St. Johns, Newfoundland. At the Valencia Observatory, of 100 occasions on which the wind at night is from the north, there is a clear sky on six occasions, the sky is one-fourth clouded on 15, one-half clouded on 15, three-fourths clouded on 27, and overcast on 34; it is raining on two occasions and foggy on one. At St. Johns, the very great percentage of fog is the outstanding feature; indeed, it is only with a calm or a southwest or a west wind that clear weather is experienced—all winds sweeping in from the ocean bring a large percentage of fog. At both stations evening and night are the clearest. The general trend of the air at both stations is from the southwest, which, as was mentioned above, brings clear weather at St. Johns, but has quite the opposite effect at Valencia. While the data do not cover a long period of time, the charts are of value especially because of their relation to trans-Atlantic flying.—*C. L. M.*

* Cf. Prof. Notes No. 1, p. 572, below.

NORMAL TEMPERATURES (DAILY):

ARE IRREGULARITIES IN THE ANNUAL MARCH OF TEMPERATURE PERSISTENT?

By CHARLES F. MARVIN, Chief of Weather Bureau.

[Dated: Washington, Sept. 10, 1919.]

SYNOPSIS.—The data examined in this study consisted of daily values of mean temperature from several old records for stations in the northeastern portions of the United States, covering periods from 1778 to 1865. These were supplemented by 45-year records from widely scattered Weather Bureau stations covering the period 1871 to 1916. The observations were reduced to 52 weekly mean values, which were subjected to the harmonic analysis, resulting in the following conclusions:

1. The annual march of daily mean temperatures is a smooth curve devoid of secondary maxima and minima or of perceptible points of inflection.

2. Marked irregularities, such as connoted by terms like the January Thaw, the May Freeze, etc., do not persist nor have a real existence. When such irregularities still remain in the means of a long record they are simply residual imprints of a single or a few fortuitously recurrent extreme or unusual events at or near the time in question.

3. (*a*) The Fourier series is a simple but powerful and quite adequate mathematical equation for the analysis of the annual march of temperature and the determination of daily and other approximate normals, even from relatively short records. (*b*) From the examination thus far made of United States data it appears the series must stop at the second term, which seems very small or inconsequential for the northeastern section. (*c*) It is fully recognized that the ultimate normal curve of annual temperature may not be quite represented by the harmonic equation of the second order. It is believed, however, that any systematic departures which may ultimately be disclosed by very long records will not be of a periodic character. Accordingly, an equation of the following form seems likely to suffice for the most refined studies:

$$T_r = A_0 + a_1 \cos(\theta_r - \phi_1) + a_2 \cos(\theta_r - \phi_2) + f(r)$$

As far as known at present, $f(r)=0$. The longest records now available here are insufficient to evaluate it.

4. Monthly means are quite inadequate for the analysis of the annual march of temperature because many important characteristics are lost in monthly summations. Moreover, uncertain corrections are required to equalize monthly intervals and allow for the "curvature" in the temperature changes within the month. The week as a subunit is a happy medium between the month and the pentad and is decidedly superior to both.

Meteorological literature contains a large number of discussions of the daily and seasonal march of temperature through the annual cycle. Familiar terms, such as the May Freeze, or Ice Saints, the January Thaw, Indian Summer, and the like, testify to the wide prevalence of the conviction in many minds that peculiar irregularities in the annual march of temperature persist or recur with greater or less certainty at particular times and seasons.

This paper is followed by a very interesting abstract of much of the literature on this question, prepared by the Weather Bureau librarian, Prof. C. F. Talman.

From time to time in the past the Weather Bureau, as has been the case with other meteorological services and independent observatories, has published so-called normal values of temperature and other data deduced from a careful discussion of the observations available at the time. As the length of the record has increased with the lapse of years the values of the "normals" have been "revised," a procedure or necessity which, in itself, discredits or makes incongruous the logical significance[1] of the term "normal."

The purpose of the present paper is to examine this whole question comprehensively. This is the more necessary because an examination of Prof. Talman's compendium clearly indicates that affirmations as to the reality of the Ice Saints and like peculiarities are based on a study of but a fragment of the data comprising the annual march of temperature.

[1] See Monthly Weather Review, 1918, 46: 515.

PHYSICAL CONSIDERATIONS.

Throughout the entire present considerations all the phenomena of the *diurnal* march of temperature are wholly disregarded. The data and conclusions apply to only a daily mean temperature or other representative value, as a maximum or minimum temperature, or a value at some particular hour of a single day.

The temperature at any station on the earth's surface is dominated primarily by the effective local intensity of solar radiation. Confining attention to the major variations in effective solar radiation, which depend on the revolution of the earth around the sun and the inclination of its axis to the ecliptic, we see that this dominating control of daily average temperatures is purely a periodic sequence with all the characteristics of a harmonic function. We must, therefore, expect that the normal annual march of temperature can be represented more or less closely by a harmonic function—a Fourier series.

Modifying variations of the average daily temperature are clearly caused by progressive or seasonal variations in the phenomena of the general circulation of the air and other minor controls on local temperature. However, perhaps all of these minor controls are themselves a function of the dominating control by effective solar radiation, and therefore become periodic and harmonic.

In the long run, therefore, we should expect the normal annual march of temperature to be a smooth, regular curve, devoid of secondary maxima and minima values.

If, however, claims are set up that secondary maxim and minima exist and persist indefinitely at particular places on the annual curve, then a physical cause and explanation of such irregularities is needed. It is recognized that some explanations, based on systematic shifting of winds, have been offered in a single or a few cases, but this still leaves unexplained their physical cause, as likewise that of a number of other equally conspicuous irregularities which appear in the march of temperature when the relatively short records now available are examined in the customary way.

THE DATA IN GENERAL.

It is well known that the simple average values of the daily temperatures, even for a long, homogeneous series of observations, show many irregular sequences of secondary maxima and minima. With short records these irregularities are striking; with longer records the alternations are less developed and seem to tend to disappear as the number of observations increases, which tendency confirms expectations reached from physical considerations that ultimately the average of centuries of observa-

tions of daily temperatures forms a smooth annual curve devoid of secondary maxima and minima.

Few full and authentic records anywhere in the world exceed a length of 150 years. In the United States, few records, even supplemented by those of the Weather Bureau, attain to a length of a hundred years. Many good records of 45 or more years are now available for Weather Bureau stations. A preliminary and tentative examination has been made of the frequency distribution and standard deviation of some of these records of temperature for winter months for the stations at Washington and Baltimore. The results indicate that the mean temperature for any one day is just as likely as not to differ from the normal by more than 6.°1 as less. The same data indicate that the probable error of the mean of 40 years' daily observations is more than $\pm 1.°0$; also the probable error of a weekly mean is about $\pm 0.°4$, and of a weekly mean of 15 years is about $\pm 0.°7$. These numerical data deduced from the observations strenghten confidence in the expectations reached from physical considerations and the cursory examination of the data and tend to show that the irregularities found in the daily means of present short records are largely, if not wholly, *accidental*, and therefore not persistent, and are chiefly caused by paucity of data. If this is true the features will be absent from the means of very long records.

Smoothing methods.—Without exception probably every one concedes that some method of eliminating the irregularities of such data as the direct average values in short records of daily temperatures is necessary in securing therefrom approximate normal values. The popular methods of plotting the observations and drawing smooth free-hand curves, as also the use of such smoothing formulae as $\frac{1}{4}(a+2b+c)$ and others of a higher order, must be regarded as very unsatisfactory in comparison with the use of a mathematical equation embracing the whole cycle whenever the latter is available. Since for the purposes of the present problem the physical considerations mentioned, as also the experience of others, clearly indicated that the normal annual march of temperature is well represented by a harmonic equation of low order, this was adopted as the simplest and most dependable means available for the analysis and comparison of many temperature records to determine the reality of the irregularities claimed to exist by some. Expectations have been very fully verified and confirmed by the experience gained in the execution of the work itself and firmly establish the conviction that the harmonic equation of the first or second order is decidedly the best approximation available of the annual march of temperature. How this may be improved is indicated by the form of equation suggested in the synopsis.

To inspire, if need be, a fuller measure of confidence in the superiority of the mathematical curve over one drawn by hand, or over a result secured by some smoothing formula, it may be pointed out that the hand has no choice but to guide its way *crudely* among closely adjacent points located by more or less discordant data and without power of discernment of the control and influence which the data fixing more distant points should exercise. The same thing is true to a much greater degree in simple smoothing formulae commonly employed. Indeed, Ryd[2] has pointed out that an arbitrary smoothing formula becomes sufficient and adequate only when its terms embrace *all* the observations, in which case it is then equivalent to, but not necessarily identical with, some designated mathematical line.

[2] Ryd. V. H. On the computation of meteorological observations.

The daily mean of even 40 years of observations is, after all, backed by only the paltry number of 40 observations, since each daily value can have only unit weight. The annual mathematical curve computed from the daily values for 40 years, however, is backed by nearly 15,000 observations, and each daily value calculated by the equation is, in reality, supported by thousands of adjacent observations, a result unattainable in any other way without centuries of observations.

In the present case both theory and experience show that the Fourier series converges with extreme rapidity. For a large section of the northeastern part of the United States a single or fundamental harmonic term is found entirely adequate to represent the observations for more than 100 years, while elsewhere harmonics of higher order than the second are quite unnecessary; indeed, from certain points of view their introduction tends to mar a good result rather than improve a poor one.

Finally, it may be stated in behalf of the mathematical methods that the least square calculation of the coefficients of the Fourier series is much more easily accomplished than for any other form of equation with a like or even less number of unknown coefficients to evaluate. Much of the prevalent aversion to the use of strictly mathematical methods of combining observations would be largely dissipated if investigators once fully learned how really simple and mechanical many of the processes are or may be made to be. In this problem mechanical devices for effecting the harmonic analysis (and synthesis, as both are involved) may of course be used, but it seems probable the arithmetical method is simpler and better since it handles the numerical data directly and obviates all curve drawing and readily yields final results in the numerical form actually required.

THE DATA AND THEIR ARRANGEMENT FOR ANALYSIS.

No attempt will be made to give in this paper the simple arithmetical steps necessary in the calculation of the few harmonic coefficients required, although the importance is recognized of setting out these steps clearly for the benefit of beginners, and it is hoped this may be done in another connection. It is desired, however, to call attention to some features of this analysis which appear to be original and sufficiently advantageous to merit wider adoption in other meteorological studies.

It is well known that the harmonic analysis of data is most readily effected when the observations cover one complete cycle and fall at exactly equal intervals of time or points of separation; also that the number of intervals are exactly divisible by 4, and with some additional advantages if divisible by 8. Unfortunately the only factors of the common year which may be considered are 5, 73.

Dove's 73 intervals of 5 days or the pentad is fine for some purposes, but useless in the harmonic analysis, because 73 is not divisible by 4 or 8. Gen. R. Strachey [3] used this period, however, by progressively merging one pentad into the 72 remaining ones, thus satisfying the arithmetical demands, but the merging process is tedious, and, at best, the result is a makeshift. The common monthly intervals are of unequal length, and, therefore, unsatisfactory, although frequently employed. The interval, moreover, is too long for the best results. The familiar decade interval would be of great convenience if of rigorously equal length, but as actually used the lengths are indiscriminately unequal by a large propor-

[3] Strachey, Lieut. Gen. R. On the computation of certain harmonic components. Proceedings Royal Soc., Vol. XLII, 1887, p. 61.

tionate part and if made rigorously 10 days long the sub-unit is far from being an aliquot part of the year.

THE WEEK IS THE BEST SUB-UNIT.

Meteorologists have seemingly been slow to recognize the superior advantages of the week as a convenient sub-unit for the discussion of annual meteorological data. Its greater length over the pentad is a real advantage and its shortness compared with the month or the decade is also greatly in its favor. Finally, its crowning superiority for general purposes, including the harmonic analysis, is found in the ease with which the one extra day over 52 weeks in a year may be merged into some one week, and thus realize exactly 52 subunits of the cycle and satisfy practically and easily all requirements. It may be noticed that in this case the mathematical week has a length of $7\frac{1}{52}$ days. If the count begins with January 1, the fraction of a day accumulates progressively and becomes one-half of a day after 26 weeks, which falls about June 2, at about which time the one extra day of the year may be absorbed by including eight days instead of seven in a single week. However, for the treatment of temperature data, it is believed to be still better to merge the extra day into a week about the *middle of July* because the temperatures are then more nearly stationary and the arithmetical effect of including or excluding an extra day in one week is most inconsequential. After a mature consideration of the whole question, I have adopted the following standard sequence of exactly 52 week like sub-units of the year and believe that meteorologists will find this subdivision of the annual cycle well suited to many purposes.

The cycle of weeks may, of course, start at any desired date, but it is considered highly convenient, if not essential, that the cycle divide at 0 hours January 1; that is, January 1 to 7 must be one week of the standard series but need not necessarily be counted as the zero week, since for different purposes it may be desirable to start the count with another week, as, for example, in studying precipitation and drainage, to start the week falling about the 1st of November.

July 16 is chosen as the extra day and is merged into week July 9 to 16. In leap years February 29 is similarly merged in the week February 26 to March 4. In full quadrennial years February 29 must of course be given only one-fourth the weight when combined with data for other dates. Without appreciable error, the mean of seven daily values may be considered as the average value for the mid date of the week. Accordingly, the weeks are designated by the date of the midday as January 1 to 7 designated January 4, July 2 to 8 as July 5, etc.

End correction.—Every complete cycle must, of course, close upon itself. In the year, for example, the fifty-third weekly value of temperature must be identical with the first weekly value. As a rule, the observational data will not satisfy this condition and a correction may be required—here called an end correction—to allow for the failure of the data to close properly as shown by the difference between the first and the fifty-third value of the cycle. This correction in harmonics is mathematically similar to the correction required in problems of triangulation in order to make the sum of the observed angles of a triangle equal to 180°. The whole matter is mentioned at this point simply to emphasize the advantage in temperature studies of starting the count of weeks in *midsummer*. The week of July 5 is preferred and recommended because irregular temperature fluctuations are then much smaller than in December and January, and the end correction will frequently be found so small as to be quite negligible and unnecessary.

In accordance with the foregoing, therefore, the standard schedule of weeks with dates and serial numbers for temperature studies is as followa:

Standard schedule of weeks for temperature studies.

Date.	Number.	Date.	Number.	Date.	Number.	Date.	Number.
July 5....	0	Oct. 5....	13	Jan. 4....	26	Apr. 5....	39
July 12[1]..	1	Oct. 12...	14	Jan. 11...	27	Apr. 12..	40
July 20...	2	Oct. 19...	15	Jan. 28...	28	Apr. 19..	41
July 27...	3	Oct. 26...	16	Jan. 25...	29	Apr. 26..	42
Aug. 3....	4	Nov. 2...	17	Feb 1....	30	May 3...	43
Aug. 10...	5	Nov. 9...	18	Feb. 8....	31	May 10..	44
Aug. 17...	6	Nov. 16..	19	Feb. 15...	32	May 17 .	45
Aug. 24...	7	Nov. 23..	20	Feb. 22...	23	May 24 .	46
Aug. 31...	8	Nov. 30..	21	Mar. 1[2]...	34	May 31..	47
Sept. 7....	9	Dec. 7....	22	Mar. 8....	35	June 7...	48
Sept. 14...	10	Dec. 14...	24	Mar. 15...	36	June 14 .	49
Sept. 21...	11	Dec. 21...	24	Mar. 22...	37	June 21..	50
Sept. 28...	12	Dec. 28...	25	Mar. 29...	38	June 28..	51

[1] This week contains 8 days, viz, July 9–16, inclusive, and the sum of the daily data is divided by 8 to form the weekly mean.

[2] This week contains 8 days in leap year. Data for February 29, when combined with data for other days in full quadrennial years, should enter with a weight of $\frac{1}{4}$ and the weekly sum be divided by $7\frac{1}{4}$ to form the weekly mean.

While the schedule of weeks designated above has been finally adopted as the best, the daily observations herein employed were originally tabulated strictly on the calendar dates, which necessitated application of the *end correction* for the year beginning with the first week of January. Moreover, the week of July 20, instead of July 5, was first chosen as the zero week, and the harmonic analysis was made entirely on this basis. When it was finally found that July 5 is, for several reasons, the best zero date for general work it was easy to adjust the equations found to this end by an appropriate change in the phase constants ϕ_1 and ϕ_2 which are the only terms affected.

Stations considered.—Two groups of data have been examined. Schott [4] has published daily means of temperature from certain early records prior to the origin of the Weather Bureau. Certain of these have been introduced for comparison with the Weather Bureau records for later dates.

Weekly means reduced from these appear in Table 1, Nos. 1 to 7, inclusive. In Table 2 is also introduced Equation No. 23*a*, which represents a long record of observations at New Haven, Conn., from 1778 to 1865, which were most carefully coordinated and discussed by Messrs. Loomis and Newton [5]. The authors reduce the New Haven observations to monthly means for the whole series, which, after correcting for curvature and inequality of length of the months, were fitted by the following complete harmonic equation:

$$T_x = 49.11 + 22°.92 \sin(x + 263° 38') + 0°.29 \sin(2x + 345° 24') + 0°.45 \sin(3x + 229° 50') + 0°.02 \sin(4x + 150°) + 0°.38 \sin(5x + 54° 31') - 0.08 \cos 6x,$$

in which x is reckoned from January 15

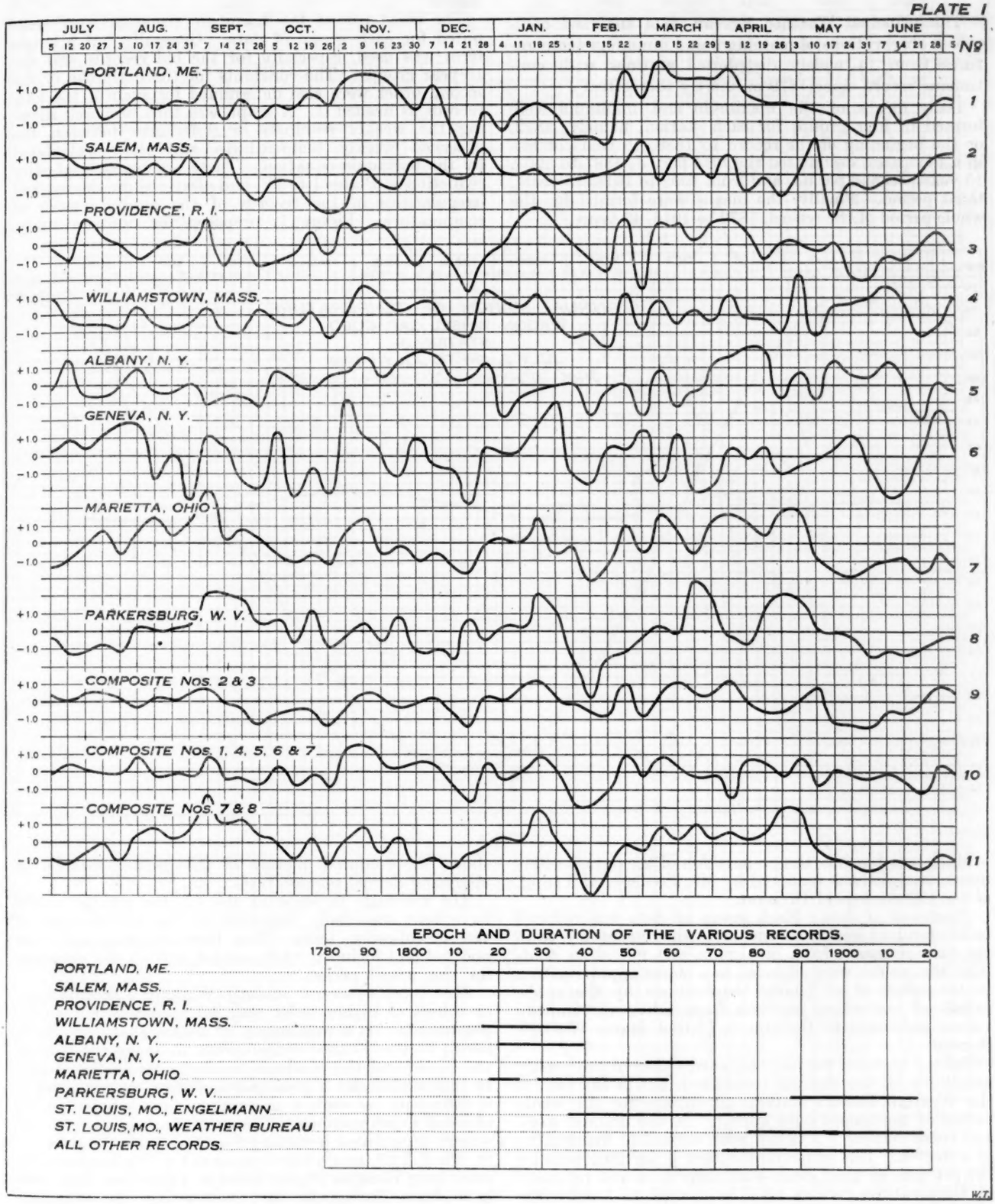
Since this equation contains 12 constants, it fits the 12 monthly observations perfectly. Equation 23a, Table 2, is two terms of the Loomis equation transformed to the cosine function and with abscissas reckoned from July 5.

Neither daily nor weekly means are available for this record, hence no annual diagram of weekly residuals is possible.

[4] Schott. Tables, distribution and variation of atmospheric temperatures in the United States, p. 187.

[5] Loomis, Elias and Newton, H. A. Meteorology of New Haven. Trans. Conn. Acad. Arts and Science, vol. 1, pt. 1,1866. p. 194.

PLATE I


JULY
AUG.
SEPT.
OCT.
NOV.
DEC.
JAN.
FEB.
MARCH
APRIL
MAY
JUNE
No
PORTLAND, ME.
SALEM, MASS.
PROVIDENCE, R. I.
WILLIAMSTOWN, MASS.
ALBANY, N. Y.
GENEVA, N. Y.
MARIETTA, OHIO
PARKERSBURG, W. V.
COMPOSITE Nos. 2 & 3
COMPOSITE Nos. 1, 4, 5, 6 & 7
COMPOSITE Nos. 7 & 8
+1.0
0
-1.0
1
2
3
4
5
6
7
8
9
10
11

EPOCH AND DURATION OF THE VARIOUS RECORDS.
1780 90 1800 10 20 30 40 50 60 70 80 90 1900 10 20
PORTLAND, ME.
SALEM, MASS.
PROVIDENCE, R. I.
WILLIAMSTOWN, MASS.
ALBANY, N. Y.
GENEVA, N. Y.
MARIETTA, OHIO
PARKERSBURG, W. V.
ST. LOUIS, MO., ENGELMANN
ST. LOUIS, MO., WEATHER BUREAU
ALL OTHER RECORDS.

W.T.

WEATHER BUREAU STATIONS.

The principal Weather Bureau data analyzed comprised observations of maximum and minimum temperatures from 14 widely distributed stations with continuous record since 1872 or shortly thereafter.

Daily means of the maximum and minimum were formed in four groups for each station, namely, 1872, or the beginning of the record to 1886, 15 years or less in a few cases, designated the first period; 1887 to 1901, 15 years, second period; and from 1902 to 1916, 15 years, third period. Finally, the means were formed for the whole period of the record, 1872 to 1916, 45 years.

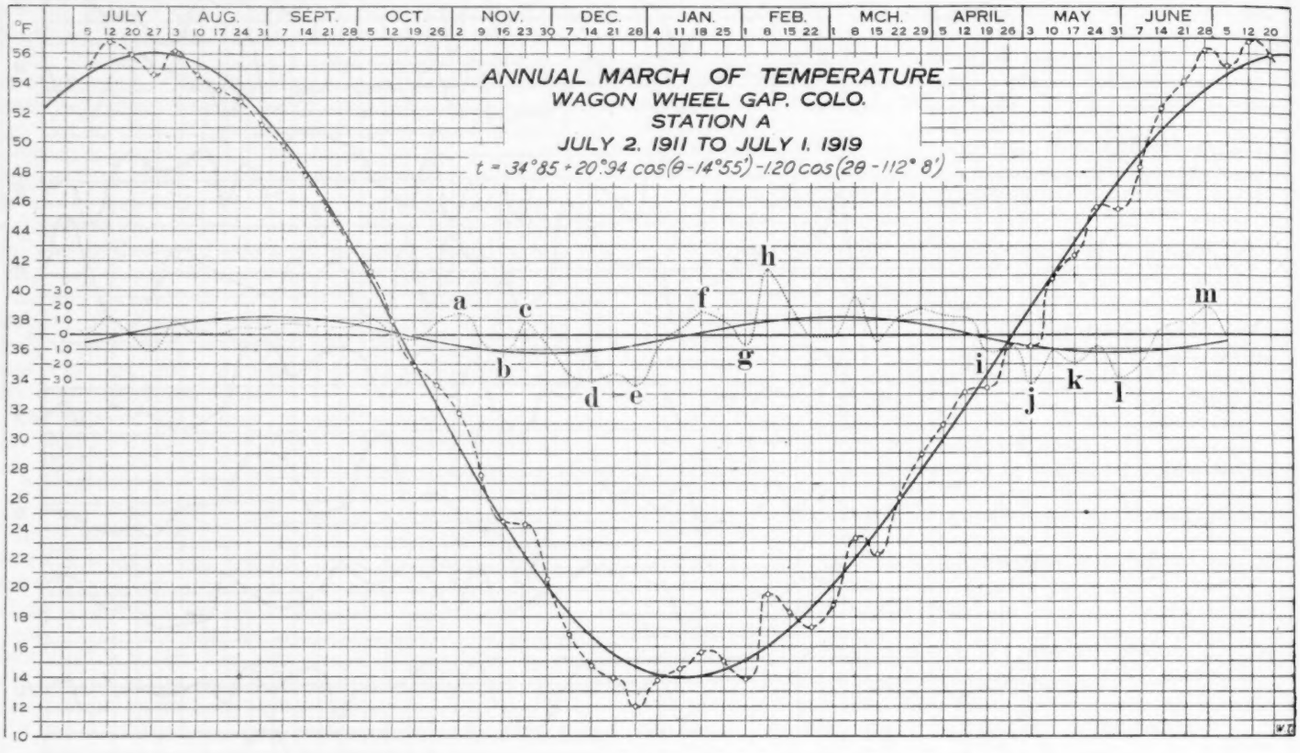


FIG. 1.

Much assistance in the preparation of the data for harmonic analysis was rendered by Mr. Frederic A. Young, of the Climatological Division.

Treatment of data.—Each group of data was reduced to 52 standard weekly means, and, when necessary, as in the case of means from maximum and minimum readings, the values were adjusted to a closer approximation to the means of 24 hourly observations by the application of corrections derived from tables of monthly values published in Bulletin S, United States Weather Bureau.

Table I contains the fully adjusted values of the weekly means for all the stations considered, but in the case of the Weather Bureau stations the means for the whole period of the record only appear. In the original work and computations all values were carried to hundredths of a degree. This order of accuracy is justified because the problem in hand deals with differences and residuals of temperatures, which may be carried to hundredths of a degree even though the absolute value of the temperature may be in some doubt. However, to save space, the table gives the values only to the nearest tenth of a degree.

The constants of the harmonic equation were computed for each group of data. Generally but a single term was used, especially for the old records and the 15-year groups. The constants for the harmonic of the second order were also determined for such of the long records as needed it. A graph was then prepared showing the weekly residuals or differences between the observed weekly temperatures and those calculated by the harmonic equation. These are reproduced after reduction in Plates I to IV, and clearly show the marked irregularities in the records of the annual march of temperature. Figure 1, prepared for another study, shows the complete picture of the present method of analyzing annual temperatures.

The residuals in some of the 15-year groups would have been materially improved by the introduction of the second-order term. This, however, was uniformly omitted and included when needed only in the equation for the whole period.

How many terms are needed.—Whether a second term or others of higher order may be needed is not easily determined. It is well known, of course, that every term added to the Fourier series serves to make the sum of the squares of the residuals smaller. While this might be mathematically a good index of need, nevertheless it is fallacious, as such a procedure is not supported by physical considerations. The extreme amplitude of the second term found necessary for any of the data was at St. Paul, 2.27, and while computed for Washington and other long Weather Bureau records, values less than 1.00 have been disregarded in constructing the diagram, because the reality of such harmonics is to be doubted from the following considerations.

PLATE II

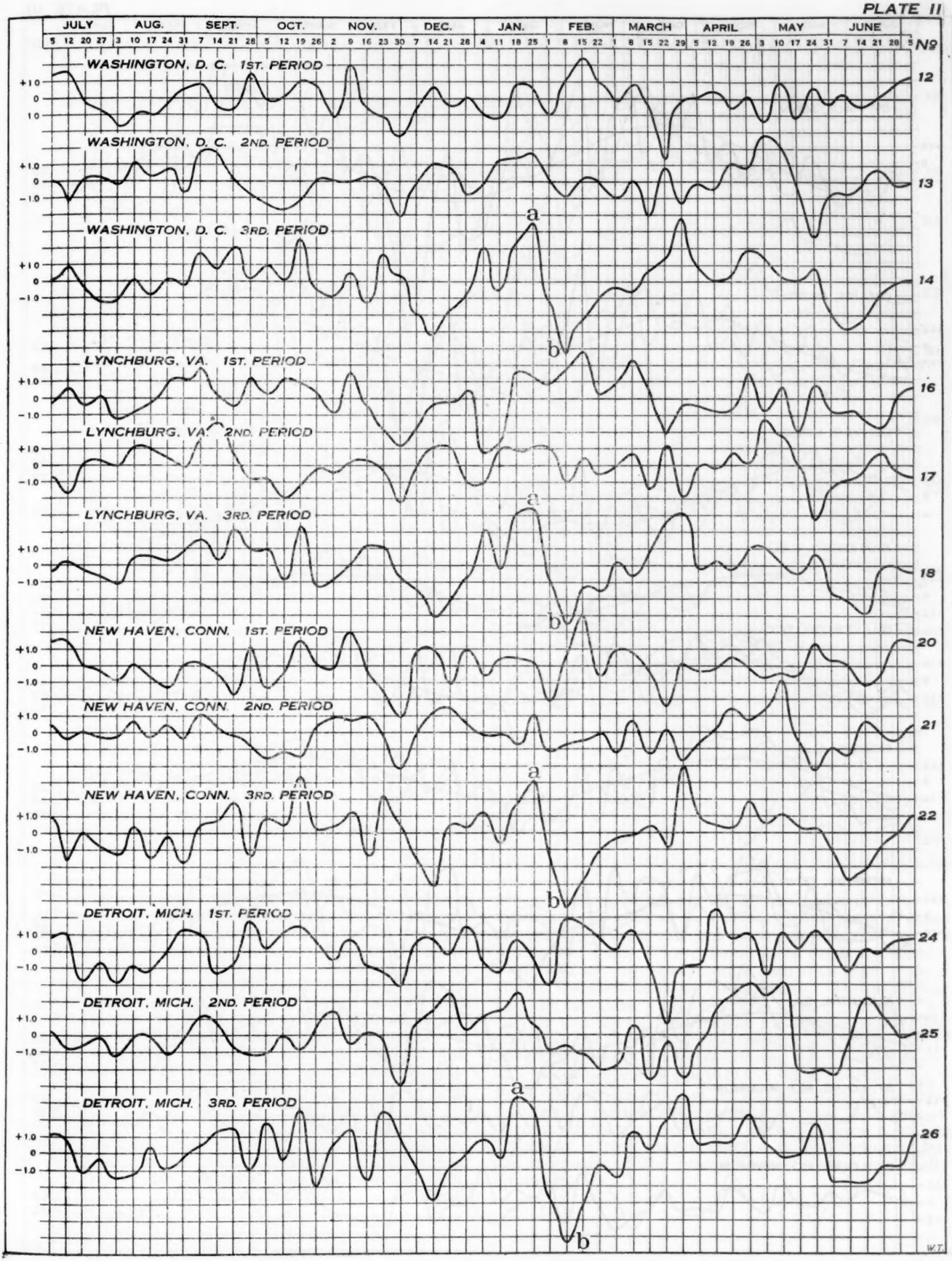

JULY
AUG.
SEPT.
OCT.
NOV.
DEC.
JAN.
FEB.
MARCH
APRIL
MAY
JUNE
No
WASHINGTON, D. C. 1ST. PERIOD
WASHINGTON, D. C. 2ND. PERIOD
WASHINGTON, D. C. 3RD. PERIOD
LYNCHBURG, VA. 1ST. PERIOD
LYNCHBURG, VA. 2ND. PERIOD
LYNCHBURG, VA. 3RD. PERIOD
NEW HAVEN, CONN. 1ST. PERIOD
NEW HAVEN, CONN. 2ND. PERIOD
NEW HAVEN, CONN. 3RD. PERIOD
DETROIT, MICH. 1ST. PERIOD
DETROIT, MICH. 2ND. PERIOD
DETROIT, MICH. 3RD. PERIOD
+1.0
0
-1.0
a
b
W.T.

PLATE III

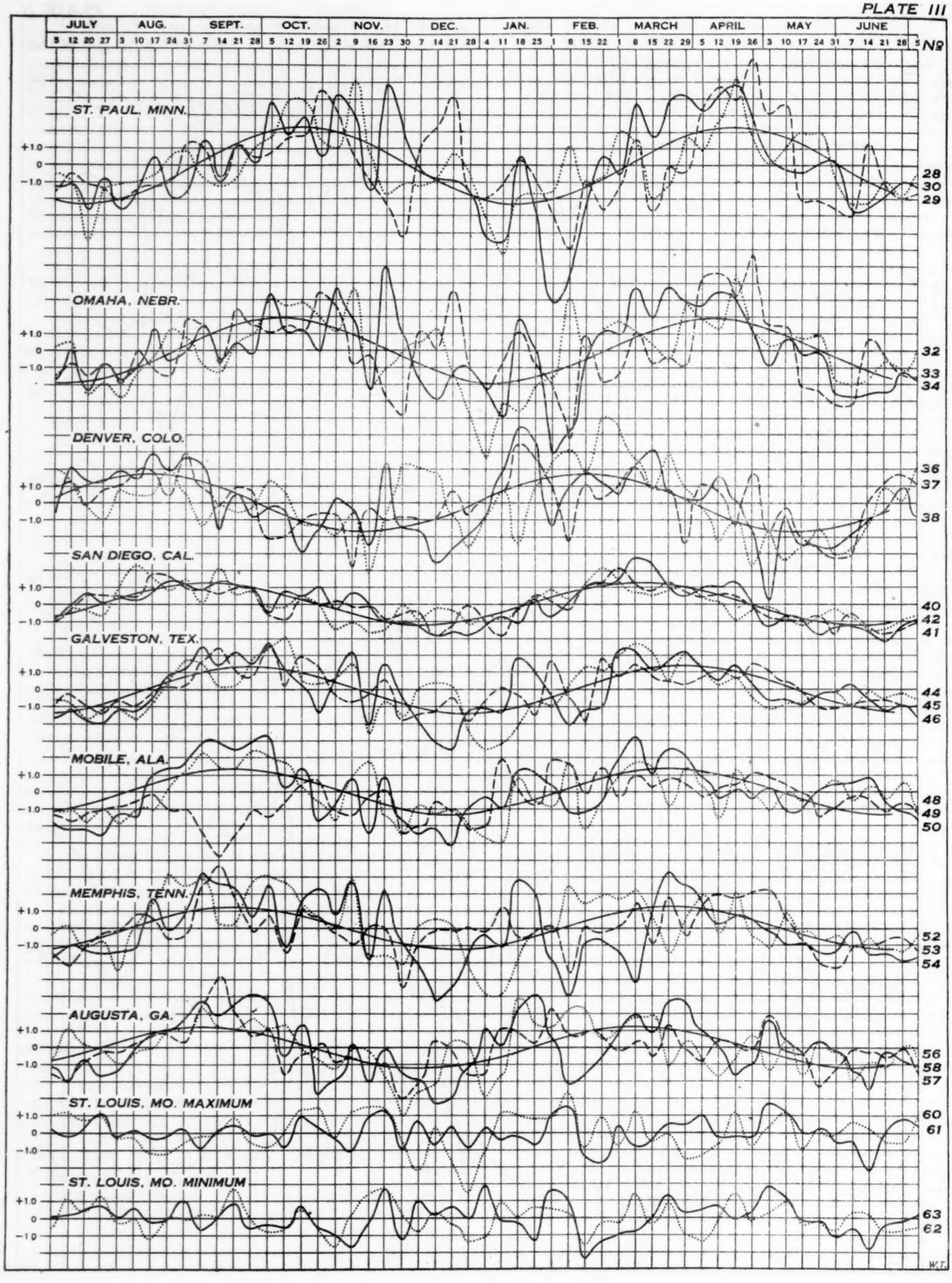
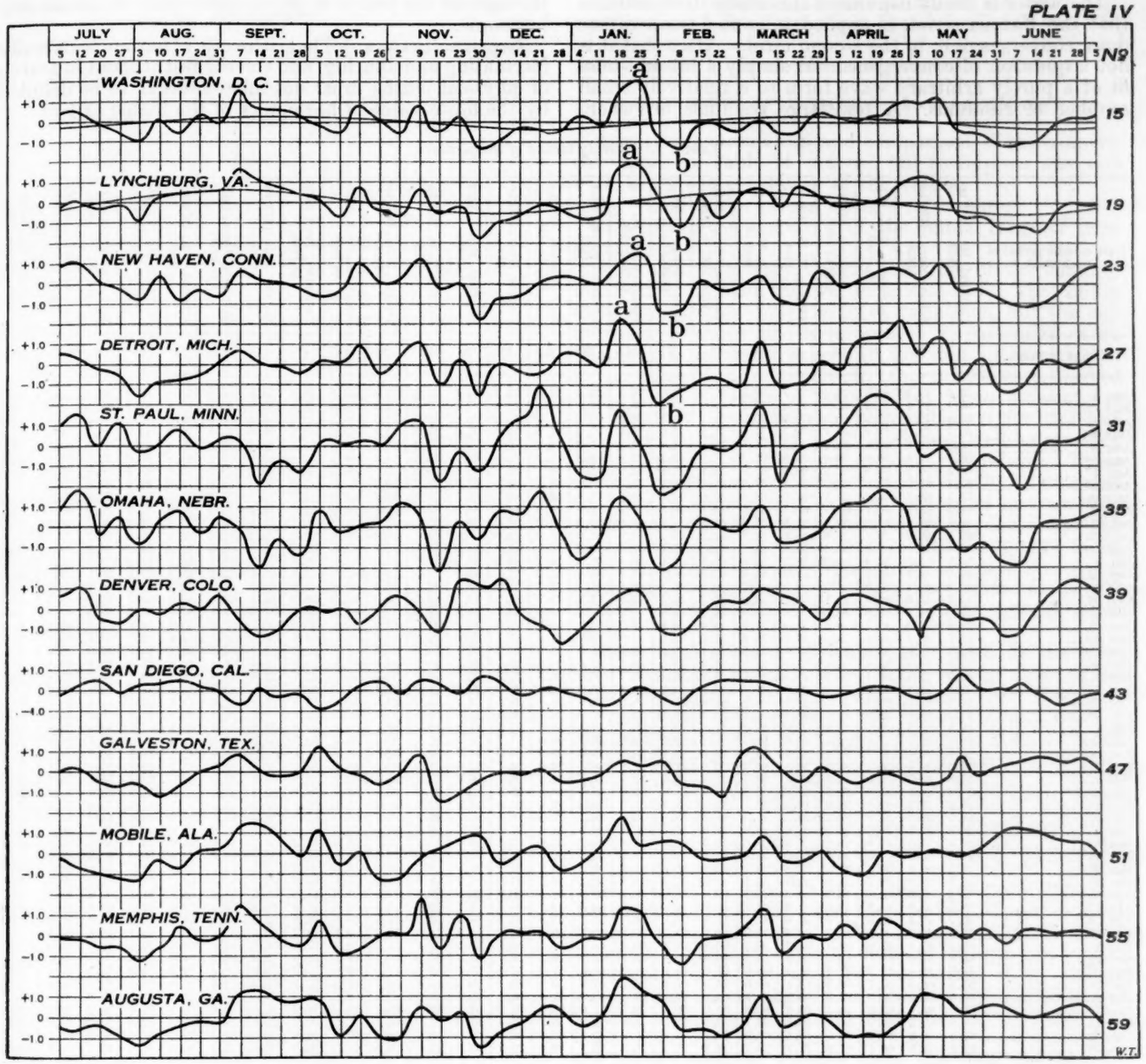

JULY
AUG.
SEPT.
OCT.
NOV.
DEC.
JAN.
FEB.
MARCH
APRIL
MAY
JUNE
No
ST. PAUL, MINN.
+1.0
0
−1.0
28
30
29
OMAHA, NEBR.
32
33
34
DENVER, COLO.
36
37
38
SAN DIEGO, CAL.
40
42
41
GALVESTON, TEX.
44
45
46
MOBILE, ALA.
48
49
50
MEMPHIS, TENN.
52
53
54
AUGUSTA, GA.
56
58
57
ST. LOUIS, MO. MAXIMUM
60
61
ST. LOUIS, MO. MINIMUM
63
62
W.T.

PLATE IV



The diagrams clearly show that, if an additional term is systematically called for, the residuals will be disposed harmonically with reference to the axis, as, for example, in the case of the superposed curves of Plate III showing the second harmonic in place, whereas the curves on Plate IV just as clearly show the absence of any systematic disposition of the residuals or the need of additional harmonic terms. Doubts on this point are easily removed if one will only himself compute a supposed coefficient of higher order and critically observe how the value thereof in many cases depends almost entirely on one or a very few favorably located residuals of large magnitude. In such cases the fit of the curve to the data is improved at one point but largely at the expense of the fit at many other places, a procedure not justified by the physics of the problem, even though the sum of the squares of the residuals may be reduced. This process of impairing the fit at one place in order to improve it at another in a certain sense tends to force the residuals into a harmonic arrangement.

The best guide I have found is to draw the second, third, and any higher harmonics desired on tracing paper and to the same scale as the diagrams. The amplitude may be anything desired. (The second harmonic for Denver was conveniently copied for this purpose.) The superposition of one of these tracings over the curve of residuals shows in a very convincing way how the residuals at one portion of the year will support and at other times oppose a harmonic of the period chosen, or possibly, if needed, systematically support it, as in the case of the second harmonics shown. In some cases, a half or a third of a year may support a higher harmonic, but the remainder of the year will quite as systematically oppose it.

The writer is firmly convinced this study demonstrates that the Fourier series, as applied to annual temperature data, converges only to the second term. After that it is not a question of convergence but simply a hit-and-miss fit of a purely arbitrary wave form to a relatively small number of residuals. A few large residuals anywhere throughout the year will give a finite value to almost any harmonic.

Important caution.—The arithmetic of harmonics is really fascinating and alluring, and the earnest student in search of physical truths must not allow himself to be deluded by the finite value of harmonics of the higher orders.

TABLE 1.—*Weekly means of temperature.*

Date middle period of each week.	Portland, Me., 1816 to 1852.	Salem, Mass., 1786 to 1828.	Providence, R. I., 1831 to 1860.	Williamstown, Mass., 1816 to 1838.	Albany, N. Y., 1820 to 1840.	Geneva, N. Y., 1854 to 1865.	Marietta, Ohio, 1818 to 1823, 1829 to 1859.	Parkersburg, W. Va., 1888 to 1917.	Washington, D. C., 1872 to 1916.	Lynchburg, Va., 1874 to 1916.	New Haven, Conn., 1873 to 1916.	Detroit, Mich., 1872 to 1916.	St. Paul, Minn., 1872 to 1916.	Omaha, Nebr., 1872 to 1916.	Denver, Colo., 1873 to 1916.	San Diego, Calif., 1875 to 1916.	Galveston, Tex., 1872 to 1916.	Mobile, Ala., 1872 to 1916.	Memphis, Tenn., 1872 to 1916.	Augusta, Ga., 1874 to 1916.	St. Louis, Mo., Engelmann-maximum, 1836 to 1882.	St. Louis, Mo., maximum, 1878 to 1918.	St. Louis, Mo., Engelmann-minimum, 1836 to 1882.	St. Louis, Mo., minimum, 1878 to 1918.
Graph number.	1	2	3	4	5	6	7	8	15	19	23	27	31	35	39	43	47	51	55	59	60	61	62	63
July 5	65.5	72.8	69.3	70.4	72.1	69.3	71.9	75.2	76.5	76.6	71.0	72.2	71.3	76.2	71.5	65.4	83.0	80.6	80.0	80.0	87.4	87.1	69.3	70.1
July 12	67.1	73.1	71.3	69.8	71.4	70.7	72.7	74.8	76.9	77.1	71.8	72.7	72.2	77.8	72.7	66.4	83.4	80.5	80.4	80.4	88.4	88.5	70.9	71.0
July 20	67.6	72.9	72.3	69.8	72.6	70.7	75.7	75.1	76.5	77.1	71.4	71.5	70.9	76.0	71.8	67.2	83.2	80.6	80.4	81.0	87.5	87.5	69.8	70.6
July 27	65.7	73.0	71.3	69.7	72.3	71.5	74.2	75.2	76.1	77.0	71.2	72.4	71.9	76.8	71.7	67.1	83.2	80.6	80.4	80.6	87.6	88.2	70.0	71.2
Aug. 3	65.8	72.6	70.5	69.0	72.3	71.8	72.2	74.4	75.2	75.9	70.4	71.0	70.2	75.2	72.1	67.8	83.4	80.4	79.5	80.0	86.6	87.6	68.4	70.0
Aug. 10	66.1	71.5	70.8	69.4	72.5	71.2	72.8	75.1	75.6	76.2	71.1	71.0	69.7	75.6	71.4	68.1	82.6	81.1	79.6	80.1	86.0	87.2	68.9	69.7
Aug. 17	64.5	70.9	68.8	67.2	69.9	67.2	72.4	73.8	74.0	75.3	69.1	70.1	69.5	75.2	70.9	68.5	82.8	80.2	79.8	79.6	85.7	86.9	67.9	69.8
Aug. 24	63.7	69.0	68.0	65.5	68.4	67.4	69.8	72.4	73.4	74.1	68.4	69.0	67.3	73.0	69.3	68.2	82.9	80.2	78.1	78.9	84.8	84.6	66.8	67.0
Aug. 31	62.1	68.3	66.4	64.1	67.0	63.4	69.0	71.0	71.5	72.6	66.7	68.1	66.1	72.0	68.3	67.9	82.4	79.4	77.0	77.6	83.3	84.3	64.9	66.2
Sept. 7	61.3	65.4	66.1	62.7	63.7	65.1	68.8	70.8	71.2	72.0	66.2	66.7	64.0	69.4	65.0	66.9	82.0	79.2	76.8	77.6	82.1	83.0	64.6	65.4
Sept. 14	57.3	64.4	61.5	59.3	61.8	62.4	64.0	68.8	68.3	69.4	64.0	64.0	59.7	65.3	61.8	67.2	80.1	77.9	74.1	75.8	78.4	80.3	60.6	61.9
Sept. 21	56.1	60.2	60.4	56.8	59.2	58.2	62.3	66.2	66.0	67.0	61.6	61.4	58.2	64.1	60.4	66.3	78.4	75.7	71.3	73.4	75.4	78.2	57.3	59.8
Sept. 28	52.6	56.9	56.8	55.4	56.0	55.7	59.5	62.5	63.4	64.4	59.1	58.7	54.9	60.6	57.7	65.6	76.9	73.9	68.6	71.3	73.3	74.8	54.6	57.1
Oct. 5	50.7	55.3	54.4	52.0	55.3	56.0	56.1	60.0	60.4	61.8	56.2	56.2	53.0	59.6	54.9	64.0	76.4	72.2	67.3	69.1	71.4	73.8	52.8	55.7
Oct. 12	47.9	53.1	52.2	48.7	51.7	49.6	53.0	56.1	57.4	58.6	53.9	53.3	49.9	55.3	52.0	63.3	73.6	68.6	63.2	65.0	67.1	70.1	48.8	51.6
Oct. 19	45.8	48.4	50.8	46.4	48.3	48.5	50.8	55.2	56.1	57.4	52.7	51.2	46.5	52.1	48.4	63.0	71.2	66.9	61.7	63.5	62.8	66.2	44.7	48.2
Oct. 26	42.3	45.0	46.8	42.1	46.2	44.2	47.7	50.4	52.8	53.9	49.1	46.9	42.6	48.8	46.4	62.2	68.6	63.4	57.9	60.0	60.7	62.2	43.3	44.5
Nov. 2	41.0	42.6	45.8	40.5	43.4	46.7	47.2	48.4	49.4	51.2	46.6	44.7	39.8	46.2	44.1	60.6	67.0	61.3	56.1	57.7	57.6	60.8	41.7	43.4
Nov. 9	38.5	41.8	42.7	39.4	41.4	41.9	45.4	46.6	48.3	50.1	45.0	42.6	36.4	42.0	40.8	60.1	65.9	60.7	55.2	56.9	54.1	57.9	39.1	41.8
Nov. 16	35.7	38.4	40.5	35.9	37.6	38.2	41.1	43.2	44.5	46.7	41.0	37.7	29.8	35.8	37.3	58.9	61.6	58.6	50.3	54.1	49.0	52.5	35.1	36.1
Nov. 23	32.2	35.5	36.9	32.6	36.0	34.6	39.4	42.2	42.8	45.0	38.8	36.2	27.7	34.9	37.6	57.5	62.1	57.2	49.6	52.5	44.1	51.0	31.6	35.5
Nov. 30	28.8	34.8	33.4	30.6	34.2	34.3	36.6	38.2	39.1	41.4	34.9	32.1	23.5	30.9	35.6	57.3	58.9	53.7	45.4	49.0	43.8	46.8	30.4	32.2
Dec. 7	28.0	32.4	32.4	28.5	32.0	30.7	35.2	36.4	37.7	40.5	33.8	31.3	22.0	29.4	34.2	56.3	57.7	52.8	44.8	48.3	39.4	45.4	27.8	30.3
Dec. 14	23.8	29.8	29.7	24.9	28.8	31.4	33.1	34.2	36.5	39.4	32.2	29.0	20.2	26.9	31.1	55.1	56.3	52.1	43.0	47.5	35.8	41.9	25.2	27.6
Dec. 21	20.2	28.2	26.4	23.2	27.3	24.9	31.3	35.0	35.0	38.6	31.1	28.0	19.4	25.9	29.6	54.8	55.4	51.4	42.0	47.2	36.5	41.4	24.2	27.8
Dec. 28	21.4	28.6	26.9	24.5	26.8	26.7	32.2	32.8	33.8	37.5	30.1	26.6	15.1	22.4	27.8	54.3	53.9	49.7	40.3	46.5	37.8	39.3	25.3	24.5
Jan. 4	19.3	26.2	26.7	22.9	23.0	25.2	31.8	32.8	33.7	36.2	29.0	25.3	11.9	19.9	28.1	53.8	53.4	49.6	40.1	45.3	37.1	38.5	24.0	23.4
Jan. 11	19.7	25.5	27.5	22.0	23.5	21.7	31.3	32.1	32.8	35.9	28.0	24.2	10.9	20.1	29.2	53.4	53.3	50.3	40.0	45.9	36.9	37.6	24.3	21.8
Jan. 18	19.6	25.4	27.6	22.4	23.8	25.7	32.6	33.9	34.3	38.2	28.5	26.0	14.0	22.2	29.8	53.6	54.1	52.0	41.7	47.8	37.3	40.8	24.4	24.6
Jan. 25	19.4	24.6	26.7	20.8	22.8	26.0	30.8	33.1	34.8	38.5	29.0	24.7	12.6	21.5	30.4	54.1	54.2	51.0	41.9	47.7	39.7	40.4	25.7	24.4
Feb. 1	17.8	25.3	25.9	19.5	21.3	23.0	31.8	30.7	32.5	37.3	26.3	22.1	10.9	20.0	29.2	53.9	55.0	51.9	41.2	48.0	37.7	38.3	23.7	21.6
Feb. 8	18.5	26.0	25.5	20.5	24.0	23.2	30.7	29.3	32.6	36.7	26.8	23.3	12.8	21.9	29.8	53.9	54.6	52.8	41.2	47.5	41.0	39.3	26.0	23.6
Feb. 15	18.9	27.3	25.8	22.0	26.5	26.1	32.8	32.8	35.0	39.2	29.0	24.8	16.3	25.6	31.8	55.1	55.4	53.2	43.8	48.7	41.5	43.0	27.4	25.5
Feb. 22	21.3	29.3	30.0	26.5	28.5	27.3	36.5	34.5	36.2	39.5	29.8	26.4	18.7	27.4	33.7	55.7	57.6	54.4	45.5	49.7	45.6	44.0	30.7	27.3
Mar. 1	24.3	32.1	26.6	26.2	28.6	29.9	36.6	37.0	37.4	42.0	31.4	27.6	21.8	29.8	35.1	56.1	59.6	56.0	47.6	51.8	46.4	46.7	30.8	30.0
Mar. 8	28.2	31.8	32.9	29.9	33.2	28.8	40.6	40.4	39.8	44.1	33.6	31.6	26.6	33.7	37.3	56.4	61.3	58.5	50.6	54.8	49.4	50.2	34.0	33.6
Mar. 15	29.2	35.4	35.0	30.8	33.5	33.6	41.8	41.2	41.1	45.3	34.4	31.6	26.2	34.9	38.6	56.6	61.9	58.9	50.6	55.0	50.8	52.8	34.3	35.1
Mar. 22	31.5	37.5	36.4	34.1	36.8	32.7	42.8	46.4	43.5	48.2	36.3	34.2	31.3	38.2	40.0	56.9	63.0	60.5	53.4	57.2	53.7	56.1	36.3	37.9
Mar. 29	34.0	39.0	39.7	36.3	41.1	35.3	47.0	47.9	46.8	50.2	40.2	37.8	35.2	41.9	41.2	57.1	65.3	62.7	55.6	59.1	57.1	57.7	39.7	40.8
Apr. 5	37.2	43.0	42.5	40.5	44.4	40.1	50.0	48.2	49.1	52.0	41.8	40.2	39.5	46.5	44.4	57.6	66.5	63.5	58.6	60.1	61.7	60.6	43.8	42.7
Apr. 12	38.5	43.8	44.3	42.0	47.8	42.3	52.1	50.5	51.6	54.5	44.7	44.6	44.4	49.9	46.6	58.3	67.8	64.9	60.1	62.0	62.5	63.4	44.7	45.9
Apr. 19	40.7	47.4	45.5	45.0	50.6	45.7	53.8	55.0	54.5	57.1	47.8	47.6	48.6	53.8	48.5	58.9	69.9	67.6	63.4	63.8	66.3	67.2	47.6	49.2
Apr. 26	43.6	49.3	49.2	47.2	50.9	46.9	57.8	58.7	57.7	60.3	50.5	51.3	51.2	56.3	50.6	59.1	71.2	69.1	65.0	66.3	69.7	70.3	50.8	52.3
May 3	46.4	53.1	51.9	53.3	55.3	50.2	60.4	61.1	60.4	63.1	52.7	52.7	52.3	57.1	51.4	59.3	72.4	70.8	67.1	69.5	70.2	71.6	51.9	53.5
May 10	48.8	54.0	54.1	52.7	56.5	53.3	60.0	62.0	63.2	65.2	56.1	56.4	52.6	61.0	55.4	60.1	74.0	72.3	69.2	71.0	73.6	74.3	54.5	56.1
May 17	51.3	56.4	57.2	57.2	61.3	56.6	61.6	64.2	64.0	65.8	57.2	57.2	57.4	62.5	57.0	60.6	75.5	73.6	70.6	72.0	75.6	75.7	56.4	57.4
May 24	53.2	60.8	57.7	59.9	63.1	60.0	63.5	66.2	66.2	67.9	59.7	60.8	60.6	65.4	59.4	61.5	77.1	75.4	72.8	73.9	78.4	77.9	59.6	60.2
May 31	54.9	62.9	59.8	62.6	65.3	60.3	65.9	67.2	67.8	69.3	61.6	61.7	62.5	66.5	60.8	62.0	78.7	77.4	73.8	75.5	80.0	78.0	61.7	61.0
June 7	59.0	65.4	63.2	65.4	68.4	60.9	68.0	69.5	69.7	71.0	63.3	64.2	63.3	68.4	63.2	63.0	80.0	78.5	76.0	76.4	81.0	81.9	62.6	64.2
June 14	59.9	67.3	64.9	66.4	69.3	63.1	68.6	71.0	71.6	72.3	65.3	67.4	67.0	71.9	66.5	63.2	81.2	79.4	77.3	77.6	82.5	84.2	64.4	66.5
June 21	61.9	69.3	64.4	66.0	68.4	67.0	70.1	72.6	73.9	74.7	67.3	69.1	68.6	73.7	69.2	63.4	81.9	79.9	78.4	79.2	84.5	85.2	66.1	67.7
June 28	62.8	71.6	69.4	67.9	71.7	70.7	72.2	74.2	75.3	75.9	69.6	70.3	69.9	74.9	70.8	64.5	82.8	80.6	79.1	80.3	86.9	85.7	69.0	69.0

TABLE 2.—*Stations and constants of the equation of the annual march of temperature.*

[$T = A_0 + a_1 \cos(\theta - \phi_1) + a_2 \cos(2\theta - \phi_2)$. θ is reckoned from July 5. Numbers correspond to Table 1 and diagrams.]

Station.	No.	Period.	An'l. mean temp.	a_1.	ϕ_1.	a_2.	ϕ_2.
			°F.		° ′		° ′
Portland, Me. 1816–1852.	1	.....	42.96	23.53	19 21	.....	... ..
Salem, Mass. 1786–1828.	2	.....	48.75	23.70	16 44	.....	... ..
Providence, R. I. 1831–1860.	3	.....	48.19	22.68	18 31	.....	... ..
Williamstown, Mass. 1816–1838.	4	.....	45.74	24.53	15 9	.....	... ..
Albany, N. Y. 1820–1840.	5	.....	48.61	24.54	13 55	.....	... ..
Geneva, N. Y. 1854–1865.	6	.....	47.14	23.26	18 49	.....	... ..
Marietta, Ohio 1818–1859.	7	.....	52.40	21.36	11 18	.....	... ..
Parkersburg, W. Va. 1888–1917.	8	.....	53.97	22.21	14 7	.....	... ..
Washington, D. C.	12	First....	54.51	22.72	16 25	.....	... ..
	13	Second..	54.76	21.79	15 14	.....	... ..
	14	Third...	54.80	21.62	14 28	.....	... ..
	15	All.....	54.69	22.04	15 20	0.32	149 33
Lynchburg, Va.	16	First....	57.16	20.59	13 8	.....	... ..
	17	Second..	56.86	20.44	13 36	.....	... ..
	18	Third...	56.68	20.16	12 31	.....	... ..
	19	All.....	56.88	20.42	13 29	0.55	117 13
New Haven, Conn.	20	First....	49.47	22.51	20 38	.....	... ..
	21	Second..	49.56	22.39	19 14	.....	... ..
	22	Third...	50.19	22.14	19 18	.....	... ..
	23	All.....	49.37	22.02	19 43	0.07	184 18
New Haven, Conn., Loomis 1778–1865.	23a	.....	49.11	22.92	17 43	0.29	127 17
Detroit, Mich.	24	First....	48.02	24.42	19 2	.....	... ..
	25	Second..	48.36	24.70	17 40	.....	... ..
	26	Third...	48.26	24.44	18 25	.....	... ..
	27	All.....	48.22	24.47	18 26	0.39	235 12
St. Paul, Minn.	28	First....	43.60	29.59	12 8	.....	... ..
	29	Second..	43.62	29.87	13 29	.....	... ..
	30	Third...	44.45	28.81	15 6	.....	... ..
	31	All.....	43.83	29.39	14 6	2.27	204 59
Omaha, Nebr.	32	First....	49.45	28.61	14 26	.....	... ..
	33	Second..	50.40	27.69	12 53	.....	... ..
	34	Third...	50.85	27.23	14 44	.....	... ..
	35	All.....	50.23	27.78	13 55	1.87	188 39
Denver, Colo.	36	First....	49.13	22.97	14 12	.....	... ..
	37	Second..	49.98	21.49	14 52	.....	.. ...
	38	Third...	49.87	20.82	15 55	.....	... ..
	39	All.....	49.66	21.53	14 59	1.69	80 1
Wagon Wheel Gap, Colo. 1911–1919.	39a	.....	34.85	20 94	14 55	1.20	112 8
San Diego, Calif.	40	First....	60.37	7.25	25 17	.....	... ..
	41	Second..	60.67	6.56	33 47	.....	... ..
	42	Third...	60.56	6.38	36 26	.....	... ..
	43	All.....	60.54	6.69	32 2	1.25	127 32
Galveston, Tex.	44	First....	70.05	15.75	14 49	.....	... ..
	45	Second..	69.47	14.69	16 44	.....	.... .
	46	Third...	69.36	14.78	17 31	.....	... ..
	47	All.....	69.63	15.07	17 0	1.38	165 8
Memphis, Tenn.	48	First....	60.99	21.03	11 54	.....	... ..
	49	Second..	61.58	19.79	11 24	.....	... ..
	50	Third...	61.33	19.87	13 21	.....	... ..
	51	All.....	61.30	20.27	12 11	1.21	152 24
Mobile, Ala.	52	First....	66.85	16.54	12 57	.....	... ..
	53	Second..	66.02	15.22	11 38	.....	... ..
	54	Third...	66.91	15.37	12 28	.....	... ..
	55	All.....	66.59	15.72	12 22	1.34	149 48
Augusta, Ga.	56	First....	64.24	17.55	12 18	.....	... ..
	57	Second..	63.62	17.68	10 49	.....	... ..
	58	Third...	63.67	17.65	10 53	.....	... ..
	59	All.....	63.84	17.69	11 48	1.18	128 22
St. Louis, Mo., E. max.	60	.....	63.33	25.69	10 37	2.26	150 36
St. Louis, Mo., W. B. max.	61	.....	64.79	24.73	13 59	2.02	174 58
St. Louis, Mo., E. min.	62	.....	46.89	23.04	12 32	1.12	114 49
St. Louis, Mo., W. B. min.	63	.....	47.72	23.75	14 52	1.10	181 32

E.=Engelmann record. W. B.=Weather Bureau record.

The terms of the Fourier series are always positive and additive. The coefficients (or amplitudes) of all harmonics will be finite *as long as any residuals whatever remain*. Critical scrutiny of the numerical summations of data which enter into the harmonic constants and tests by the superposition of tracing paper curves are the surest guides.

While this paper clearly shows how well the harmonic equation of the second order represents the *annual* march of temperature, it must be recognized the demonstration stops right there. It is just as easy to show that the Fourier series is quite *unfit* to represent the *diurnal* march of temperature, although frequently used for this purpose.

Table 2 contains the constants of the harmonic equations, and the diagrams in Plates I, II, III, and IV, bearing corresponding numbers exhibit the weekly residuals (observed minus calculated) derived therefrom.

DISCUSSION OF EQUATIONS AND RESIDUALS.

A critical examination and comparison of the numerical values in Table II can not fail to impress any one with the great constancy of the values:

A_0, which is the annual mean temperature.

a_1, which is very nearly half the annual range of temperature, and

ϕ_1, which fixes very largely the time of the summer maximum (as also the winter minimum). The values of a_2 and ϕ_2 show much greater variations, but the significance of these also is important in particular cases. We should naturally expect to find but little variation in the value of the *annual mean* tenperature when derived from 15 or 45 years of records, but when we compare the Weather Bureau records for New Haven, for example, with the Loomis record No. 23a we may well be gratified and surprised to find no greater differences. These several results are still erroneous and should be expected to differ to some extent, simply because of instrumental errors and the differing influences of exposure and the means employed in each case to deduce a true mean daily temperature from observations of a maximum and minimum, or a few readings a day with occasional breaks which mar the continuity of old records especially.

How basic climatic characteristics, such as the relatively constant annual range, stand out in spite of all these and other accidental disturbing effects is shown by the small differences in the values of a_1, whether deduced from one of the 15-year groups or from a record at a near-by station made a hundred years earlier, as, for example, Salem, Mass., 1786 to 1828, $a_1 = 23.70$, and New Haven, 1873–1916, $a_1 = 22.02$, or Marietta, Ohio, 1818–1859 $a_1 = 21.36$, and the Weather Bureau record at Parkersburg, near by, 1888 to 1917, $a_1 = 22.21$. The Loomis equation for the New Haven record, 1778 to 1865, Equation 23a, Table 2, and the later Weather Bureau record for the same station, No. 23, are striking cases of close agreement. The same order of constancy is found in the approximate dates of highest and lowest temperatures as indicated by the values of ϕ_1. These dates are of course slightly modified by the values of the second harmonic, and just what the actual dates are does not concern us much in this study, but we may make the observation in passing that the data in Schott's early records seem to indicate a slightly earlier date of maximum and minimum than now prevails. A more critical examination or analysis of the data for the whole century is necessary, however, to establish the real facts.

Just one additional point will be mentioned resulting from the somewhat different treatment given the St. Louis record. A very excellent record of daily values of maximum and minimum observations from 1836 to 1888 was discussed and published by Englemann.[6] These, supplemented by partly overlapping and subsequent records at the Weather Bureau station, have been harmonically analyzed, keeping the maximum and minimum values in separate groups. The important feature which seems to stand out is that the second harmonic is much smaller in the march of minimum than in that of the maximum, which is greater than for the mean temperatures. More data must be studied, however, to get at the

[6] Trans. St. Louis Acad. Sci. IV, p. 496–508. 1878–1886.

real physical facts back of this indication. The feature seems to be a measure of the lag exhibited by the temperature of a place in responding to the seasonal changes in effective solar radiation.

Having attained its summer maximum, the temperature falls off more slowly all through the autum than the decline in effective insolation, followed by rapid cooling in November, which slows up in December, becomes nil in January, and a reverse lag occurs during the warming up process from February to July. These considerations have a very important bearing upon the claims made by such students as Clayton [7] with reference to the immediate influence he ascribes to small irregular changes in the intensity of solar radiation in effecting noticeable changes in terrestrial weather. A critical study of the lag effects mentioned above should help to evaluate the earth's sensitivity to such influence.

Diagrams.—No verbal discussion can replace a thorough and critical examination of the diagrams which the dubious reader must make for himself if he is skeptical of the conclusions stated later. Accordingly, only a few important considerations will be brought out.

The following features of the diagrams are conspicuous:

(*a*) Without respect to length of record or locality of the station, each annual diagram shows a sequence of a considerable number of irregular pseudo-periodic alternations of crests and hollows, which vary in character from mere inflections to fully developed waves.

(*b*) In most cases the waves are better developed, or of larger amplitude and longer period in the colder months (November to March, inclusive) than in the warmer months.

(*c*) The annual number of waves can not be stated definitely because so much depends upon the inclusion or exclusion of the poorly defined minor waves. However, counting up all the diagrams and including each crest and hollow which may reasonably claim recognition, I find a quite consistent average of about 30 crests and hollows per year, or about 15 full waves. I also estimate that between 5 and 10 per cent of the number are doubtful. This leaves between 13 and 14 major waves per year, or an average interval, crest to crest, of about three and one-half to four weeks. Practically the same average result is reached by a count of the number of changes $\pm$ in the signs of the residuals, but, of course, all do not fall between the crests and hollows as counted.

(*d*) By comparing diagrams for the 15-year periods with the one for the whole period we find in every case the conspicuous crests tend to diminish and disappear. All residuals seem to tend to approach closer and closer to the axis of the diagram as the length of the record increases.

(*e*) While we necessarily assume that the weather or temperature of to-day or of this week is quite independent of the weather or temperature of the same day or week a year ago, or any other year, yet we must recognize that there is a close correlation between the temperature of yesterday, to-day, and to-morrow, and a less close relation between the temperatures of contiguous weeks. Extremes of temperature necessarily occur in spells, often of several days or even weeks duration. Such events impress themselves not only upon human attention and memory, but it is interesting to notice that in a mathematical sense a very like effect is impressed on the averages of the numerical data. A conspicuous crest and hollow, such as *a b* in the Washington record No. 14, signifies a marked alternation of unusual warm weather, culminating in a crest for the week of January 25, followed by an equally pronounced and unusual cold wave, culminating in the week of February 8. The imprint such events make on the memory is lasting and it can be effaced from the numerical average only in two ways, both of which tend to require a very long time:

(1) Obviously the subsequent occurence at or about the same date of another extreme but in the opposite sense more or less completely effaces from the numerical average the imprint of the first event. A chance of this kind, as we know, will occur only rarely. Moreover, it is nearly an equal chance that two continuous extremes will be of the same as of opposite kind and thus tend to perpetuate rather than efface each other.

(2) The other way in which the imprint left by one extreme condition is effaced from the average is simply the prolonged absence subsequently of any other like extremes. The recurrence year after year of average conditions little by little effaces the imprint one or more extremes may have produced originally. These considerations seem equally applicable to any of the conspicuous features present in all the diagrams.

(*f*) If the "January Thaw," the "May Freeze," "Squaw Winter," and "Indian Summer," are concluded to connote some of the 13 or 14 wave features which characterize even the longest records, then all the features claim equal recognition and equally need explanation. The features of weather named above have doubtless impressed themselves upon human attention because of their influence on agriculture or other critical human interests; the 9 or 10 other similar features of the annual cycle have passed unnoticed.

(*g*) The claim may be made that the Ice Saints, for example, are real enough, but the feature is eliminated because it does not fall at closely the same date each year. The mere incident of happening over a range of dates, therefore, causes it to vanish from the final mean. Such a claim is quite refuted by the diagrams, however, because if true the features would be consistently conspicuous in the short or 15-year records, and less conspicuous in the full period. Take New Haven, Conn., for example. The first period, No. 20, Plate II, shows no conspicuous warm spell late in January nor a cold spell early in May. The second period, No. 21, shows the the week of January 25 one degree above the axis, while the first half of May is conspicuously warm. The third period, No. 22, exhibits a well defined January thaw, culminating on the 25th, with May warm throughout, almost. These conspiring and opposing effects impress upon the record for the whole period, No. 23, Plate IV, a semblance of a January thaw.

The Detroit records, Nos. 24, 25, and 26, tell practically an identical story. Indeed, period for period, the Detroit and New Haven records are remarkably alike. We should really expect to, and we do find, likeness in the records of different stations for the same periods. We also find great unlikeness in records of the same or near-by stations for different times.

Critical examination of the records such as outlined in the foregoing leads to but one conclusion. Thirteen or fourteen major alterations of relatively warm and cool weekly temperatures infallibly recur irregularly year after year. These must necessarily conspire and interfere indiscriminately, and great major phenomena, traceable in the original record to a single or a few unusual events which have fortuitously recurred and combined, impress themselves upon the average of the whole record.

[7] H. H. Clayton. Effect of short-period variation of solar radiation on the earth's atmosphere, Smithsonian Misc. Colls., vol. 68, no. 3, 1917, 18 pp.

Note in the New Haven and Detroit records how the striking crests *a b* in the third period still persist in the 45-year means.

It is proper to consider at this point what would have been the outcome of this investigation if it had been feasible to use, say, 72 or 24, instead of 52 week like subunits of the cycle. It seems easy to imagine that the number and distribution of the conspicious features would be quite different. In other words, the detailed features would depend upon the method of analysis and not have a real existence.

Each striking feature on a long record is, therefore, no evidence of the persistent recurrence of peculiar irregularities, but is simply the residual scar or imprint of some unusual event, or a few which have been fortuitously combined at about the time in question. Time will inevitably efface these, but a very long time is necessary to reduce the curve to even the semblance of smoothness and simplicity. Little is gained by combining the results from many stations unless widely separated or for different periods, because all are likely to be similarly impressed by the same major irregularities. If widely separated, the averages may be smoother, but individual characteristics peculiar to a locality are very likely to be lost. The composite records Nos. 9, 10, and 11, are examples of this treatment.

Referring to the final conclusions stated in the synopsis, it is believed the foregoing studies clear away grave uncertainties and conflicting opinions concerning the annual cycle of temperature and we are now in a position to produce daily, weekly, or other normal values of any kind desired. These are much needed for the purpose of carrying out interesting and important studies which are in contemplation of the frequency distribution and standard deviations of temperature data, including more serious investigations of the cause and effect relations between terrestrial temperatures and cosmic and other influences.

LITERATURE CONCERNING SUPPOSED RECURRENT IRREGULARITIES IN THE ANNUAL MARCH OF TEMPERATURE.

By C. FITZHUGH TALMAN.

[Dated: Weather Bureau Library, Washington, May, 1919.]

The belief that periods of unseasonable heat and cold tend to recur at or about the same time from year to year has prevailed over a great part of the world for many centuries and has been the subject of extensive scientific investigation. Among the most widely recognized periods of this character are the following:

1. *A mild period in January, the "January thaw."*—This period is popularly looked for in America, especially in New England, but apparently not in Europe.[1]

2. *A cold period in April.*—This is the "blackthorn winter" of England, so called because it is supposed to set in when the blackthorn is in blossom.[2] In this connection it may be noted that in various parts of the United States so-called "winters" are popularly associated with the flowering of the redbud, dogwood, snowball, and other plants. R. Abercromby,[3] who found evidence of a recurrent cold period in Scotland, April 11–14, shows that, taking account of the change from the Julian to the Gregorian calendar, this period coincides with the "borrowing days," the last three days of March, reputed in British folklore to have been borrowed by March from April, and notorious for cold and stormy weather.

3. *A cold period in May.*—In European weather lore this is the most celebrated of the periods under discussion. Over a considerable part of continental Europe it has been popularly believed since the Middle Ages that destructive frosts were likely to occur at a certain period in the month of May, and with the elaboration of the ecclesiastical calendar these frosts became definitely associated with the days dedicated to Saints Mamertus, Pancras, and Servatius (May 11, 12, 13), or, in south-central Europe, Saints Pancras, Servatius, and Boniface (May 12, 13, 14), hence known as the "ice saints." These saints and their days are called in French *saints de glace;* in German, *Eisheiligen, Eismänner,* or *gestrenge Herren.* In Bohemia, Pancras, Servatius, and Boniface are known collectively as Pan Serboni.

Passing mention should be made of the fact that in France the full moon which occurs late in April or early in May has a bad reputation as a bringer of frosts. It is known as the *lune rousse* ("russet moon"), in allusion to the brown appearance of frosted vegetation. Both the ice saints and the *lune rousse* evidently owe their notoriety to the fact that the beginning or early part of May is a critical period in the growth of vegetation, and frosts occurring at this time attract more attention than those which occur at other seasons.[4]

4. *A cold period in June.*—This depression in temperature is generally much more pronounced in European meteorological records than the cold period in May, but has not attracted public notice to the same extent because it is generally harmless to vegetation. It is recognized in German weather lore as the *Schafkälte* ("sheep-cold"); i. e., a chilly period dangerous to newly shorn sheep.[5]

5. The *dog days* (a period of heat after midsummer) doubtfully belong in this list. Various notions prevail as to their duration and time of occurrence, but in general they may be regarded as coinciding with the crest of the annual temperature curve, rather than with any irregularity therein.[6]

6. *Squaw winter.*—In the northern United States and Canada a period of wintry weather is reputed to precede Indian summer, and is known as "squaw winter."[7]

7. *A mild period in autumn,* especially in October and November; Indian summer of North America; St. Martin's summer, after-summer, old wives' summer, etc., of Europe. Typical Indian summer weather is calm, dry, and hazy or smoky, as well as warm for the season. The corresponding period in the Old World is associated in

[1] Messrs. W. M. Esten and C. J. Mason, in a discussion of a 21-year temperature record made at Storrs, Conn., find a sharp and prominent rise in the curves of both mean and extreme temperatures between the 20th and the 25th of January, which they identify with the "January thaw" of popular weather lore. (Storrs Agr. Exper. Sta. Bull. 64, September, 1910, p. 179.) There is, however, a surprising paucity of literature on this subject.

[2] J. Wright, "English dialect dictionary," 1, p. 284.

[3] Jour. Scott. meteor. soc., 2, 1867, p. 284.

[4] Moonlight at this period is correctly associated in the popular mind with frost, because a moonlit night is also a clear night, and hence favorable for nocturnal radiation. (See A. Angot, "Traité de météorologie," 3d ed., p. 398.) There is an abundance of other literature on the subject of the *lune rousse.*

[5] K. Almstedt, "Die Kälterückfälle in Mai und Juni," 1913, p. 5.

[6] As to the dates of the dog days, see the Oxford "New English Dictionary," s. v. *dog days.*

[7] The same name is occasionally applied to a spell of unseasonably cold or snowy weather in spring, *vide* Jour. Amer. Folk-lore, 20, 1907, p. 235.

popular lore with the presence of floating spider webs (gossamer) in the air. The American Indian summer is extremely irregular in its time of occurrence,[8] so irregular as to point clearly to the fact that it is rather a *type* of weather, prevailing intermittently in the autumn, than a single recurrent irregularity in the autumnal temperature curve. The European "after-summer" has been assigned more definitely to certain dates, owing in part to its association with the names of particular saints. These dates vary widely, however, from place to place. According to A. Lehmann,[9] they range from August 15 (Julian calendar), the beginning of the "young women's summer" of Russia, to November 11, St. Martin's day, a date popularly associated with the after-summer in Germany, Holland, France, Italy, and sometimes England. Broadly speaking, two after-summer periods are recognized in Europe, one prevailing approximately from September 22 to October 9, and the other early in November.

The tendency of particular types of weather to occur at about the same period from year to year has been described by R. Abercromby[10] under the generic name of "recurrence." The phenomena classified under this head are not all peculiarties of temperature. For example, in England a rainy period, known as the "Lammas floods," is looked for about August 2–8. On both sides of the Atlantic "equinoctial storms" are expected about the time of the equinoxes, especially the autumnal equinox. In the present paper, however, we are concerned only with recurrence as a phenomenon of temperature.

Departures from a smooth annual curve of temperature have been described by Buchan and others as "interruptions of temperature." German terminology further specifies a downward inflection of the curve during the half of the year in which the temperature is generally rising as a *Kälterückfall* ("return of cold"), and an upward inflection during the other half of the year as a *Wärmerückfall* ("return of heat").[11] The irregularities in question are frequently referred to as "anomalies"; an expression justifiable on etymological grounds (*ἀνωμαλία*= unevenness, irregularity), but perhaps somewhat unfortunate because tending to suggest the idea of "abnormality." If we characterize these irregularities as "abnormal" we beg the question as to what constitutes a normal progression of temperature, and this is the very question we are trying to settle in our study of the alleged recurrent interruptions. A further objection to the use of the word "anomaly" in this connection is that the expression "thermal anomaly" has been used since the time of Dove in a special sense quite remote from the one under consideration.

The following bibliography, while not exhaustive, includes all the more important publications relating to the subject in hand, and also many contributions of minor importance which serve to illustrate the general character of the literature on this subject.

It will be observed that much the largest number of publications relate to the cold period supposed to recur in May and assigned by popular tradition to the days of the "ice saints." The first somewhat comprehensive study of this phenomenon from a scientific standpoint was made in 1834 by the astronomer J. H. Mädler, who suggested that the temperature depression experienced in Germany was due to the cooling of the air to the northeastward, where, he assumed, a large amount of heat was abstracted from the atmosphere every spring in the melting of ice over the great basin of the River Dvina. The idea that the rise of temperature in spring may be checked over extensive areas on account of solar heat becoming latent in the process of melting the ice and snow of high latitudes, or of the Alpine summits, recurs in subsequent literature.

In 1839 Adolf Erman advanced the hypothesis that the cold period in May and one in February were due to the passage of periodic meteor showers between the earth and the sun. According to this hypothesis the meteors which are visible at opposition as the well-known showers of November and August are in inferior conjunction with the sun six months later, viz, in May and February, respectively, and then cut off a certain amount of solar heat from the earth. This hypothesis was later expanded by F. Petit (1863), who sought to explain various recurrent periods of warmth, as well as cold, as due to the effect of meteors in enhancing or diminishing the insolation received by the earth. A kindred idea was that of Sainte-Claire-Deville, who, in a long series of papers in the Comptes Rendus (1865–1876), described recurrent perturbations or brusque oscillations of temperature supposed to occur at intervals through each year and suggested that these might be due to the passage of the earth through masses of cometary matter in space.

An elaborate study of the cold period in May was published in 1856 by H. W. Dove, the foremost meteorologist of his time. Dove examined the means of temperature for pentads (five-day periods) for various stations through the year and found that the third pentad of May was, on an average, colder than the second in western Russia (Courland), Germany, Belgium, France, and southern England. He recognized that this cold period was due to northerly winds, but his attempt to explain the prevalence of such winds was in conformity with his well-known hypothesis of conflicting "equatorial" and "polar" currents, which antedated correct knowledge concerning cyclones and their attendant phenomena. Dove pointed out that the winters were commonly longer and more severe in North America than in western Europe, and he believed that in the spring a strong "polar" air current, coming as a northwest wind from America, interrupted the normal flow of the mild southwest "equatorial" current then prevalent over Europe.

With the construction of synoptic weather charts, the barometric conditions that accompany depressions of temperature gradually became apparent. The cold period of May was discussed from this point of view as early as 1877 by Billwiller, and more fully by Klein (1881), Assmann (1881), Bezold (1883), and others. It was found to occur when, owing to the rapid warming of inland regions as compared with the ocean, a center of low barometric pressure develops over southeastern Europe, while high pressure prevails over the ocean to the northwest, a situation that gives rise to cold northerly and northeasterly winds in central Europe. The barometric situation attending the more pronounced fall in temperature that often occurs in June has also been studied, and this is found to coincide with the setting in of the summer rainy season over central Europe. Similar studies have been made in regard to other irregularities in the annual temperature curve, including unseasonably mild periods in autumn (Indian summer, etc.).

While the immediate causes of these interruptions of temperature have thus been made clear, it is not yet certain whether or to what extent such interruptions, with

[8] *See* MONTHLY WEATHER REVIEW, Wash., **30**, 1902, p. 27, footnote 63, and p. 440–442.
[9] "Altweibersommer," p. 61.
[10] "Principles of forecasting," 2d ed., Lond., 1885, p. 65.
[11] No English equivalents of these expressions have become established in the vocabulary. V. H. Ryd ("On computation of meteorological observations") translates *Kälterückfall* "cold-relapse." The supposed recurrent depression of temperature in the second decade of May has been called the "May dip." (Monthly Weather Rev., **30**, 1902, p. 442.)

their attendant barometic conditions, tend to recur from year to year on certain dates, such as the days of the ice saints. Irregularities in a curve showing the mean annual march of temperature as deduced from a record of fifty or a hundred years may be due to excessive departures in particular years rather than to a real tendency to recurrence on particular dates, and, on the other hand, a tendency to recurrence might not manifest itself in the mean curve, especially if, as some students have surmised, the phenomenon is one that undergoes periodic fluctuations.

A method of testing long temperature records for the existence of recurrent interruptions, which has been applied by Vincent (1882), Kremser (1900), Barnard (1900), Luizet (1907), and notably by Roche (1881), in his comparison of records made in the eighteenth and the nineteenth centuries at Montpellier, is to divide the total record into two or more parts and compare the curves based upon the partial records. This process has yielded conflicting results, as will appear from the notes in the bibliography.

Most of the literature cited below antedates the study of "centers of action." As pointed out by Arctowski, in his memoir of 1917, future investigations of the subject under discussion must take account of these important features of the general circulation. It will also be necessary to investigate the bearing of aerological data upon the subject; this has hardly yet been done except as noted under the citation of Hergesell's paper of 1900.

Lastly, it will be noted that many writers still, as in earlier times, look to cosmical causes to explain the alleged phenomena in question.

1820.

Brandes, H. W.

Beiträge zur Witterungskunde: Untersuchungen über den mittleren Gang der Wärme-Aenderungen durchs ganze Jahr. . . Leipzig, 1820.

The author discusses the annual temperature curves of 12 European stations, as deduced from pentad (five-day) means, and points out several irregularities that seem to be more or less general. A cold period in late February or the beginning of March is attributed to the fact that the sun is then rising above the Arctic shores of Europe and Asia. As the coldest time of the day in middle latitudes is shortly before sunrise, the regions in question should, the author thinks, be then having their minimum temperature. The thermal contrast between the arctic regions and lower latitudes results in northerly winds, and cold weather is thus propagated southward.

1830.

Z.

On the cause of the peculiar aspect of the air, in the Indian summer. American journal of science and arts, New Haven, **18,** 1830, p. 66–67.

Deals with optical features only.

1834.

Mädler, J. H.

Ueber die Temperatur der zweiten Maiwoche zu Berlin. Verhandlungen des Vereins zur Beförderung des Gartenbaues in den K. Preussischen Staaten, Berlin, **10,** 1834, p. 377–384.

The author, from an examination of an 86-year temperature record at Berlin, finds evidence of a recurrent cold period May 10–13, and attributes it to the melting of ice in the River Dvina.

1835.

Essay on the Indian summer, read at a meeting of the Maryland academy of sciences, by one of its members, Baltimore, Dec. 16, 1833. American journal of science and arts, New Haven, **27,** 1835, p. 140–147.

"The increased temperature which accompanies the existence of this hazy weather is referable to several causes, viz:

"1st. The prevailing wind, which, being from a southerly direction, is usually warm.

"2d. The heat radiated from the earth's surface is immediately returned (on a well-known principle), being reflected back by the haze of the atmosphere, while lastly the temperature is further increased by the condensation of both air and moisture during the formation of the foggy stratum."—p. 147.

1836.

Foot, Lyman.

Remarks on Indian summers. American journal of science and arts, New Haven, **30,** 1836, p. 8–13.

"As to the *increased* temperature, during Indian summer, we can not agree to it. From the document we have quoted (Meteorological register), it appears that the mean temperature for November is somewhat lower than that of October. It is from the quiet, placid state of the atmosphere that some are led to suppose it is actually warmer. But he who keeps an accurate record of the thermometer will find it is a mistake."—p. 12.

1838.

Mahlmann, C. H. W.

Der Indianer Sommer in Nord-Amerika, verglichen mit gewissen Witterungserscheinungen Mittel-Europas. Annalen der Physik und Chemie, Leipzig, **44,** 1838, p. 176–189.

Points out possible influences of dry fog (smoke from forest fires, etc.,) on temperature, as a cause of Indian summer.

1839.

Erman, A.

Ueber einige Thatsachen, welche wahrscheinlich machen, dass die Asteroïden der Augustperiode sich im Februar, und die der Novemberperiode im Mai eines jeden Jahres zwischen der Sonne und der Erde, auf dem Radius Vector der letzteren, befinden. Annalen der Physik und Chemie, Leipzig, **48,** 1839, p. 582-601. Also published in Astronomische Nachrichten, Altona, **16,** 1839, col. 363–366.

Advances the hypothesis that the August and November meteor showers pass between the earth and the sun in February and May, respectively, thus cutting off a certain amount of solar radiation from the earth and producing cold periods in the latter months. This hypothesis, especially as bearing on the cold period in May, attracted wide scientific and popular interest and is discussed by many subsequent writers.

1840.

Erman, A.

Sur les étoiles filantes périodiques des mois d'août et de novembre. Comptes rendus de l'Académie des sciences, Paris, **10,** 1840, p. 21–32. Also published in Annales de chimie, Paris, **73,** 1840, p. 315–333.

Sets forth same hypothesis as his paper of 1839, cited above.

1843.

Mädler, J. H.

Über den Gang der Temperatur im Laufe des Jahres. Jahrbuch für 1843, von H. C. Schumacher, Stuttgart & Tübingen, 1843, p. 70–122. (2d pagination.)

Discussion of Berlin temperature record (110 years). The author finds recurrent irregularities as follows:

A warm period, January 9–19; a cool period, May 9–12; an abnormal rise of temperature, May 31–June 3, followed by a fall, June 3–5, and retardation of the normal rise until the 11th; a cool period June 16–22; a sudden fall September 25–30. He agrees with Brandes in ascribing the cold period in January, and one found by Brandes at various stations in February, to the propagation of cold weather from the Arctic coasts of Europe, where the sun is then rising. As to the cold period in May, he raises objections to Erman's meteorite hypothesis, and reaffirms his belief in the explanation given in his own earlier memoir (melting of ice in northern rivers).

1844.

Jacobs, M.

Indian summer. Literary record and journal of the Linnaean association of Pennsylvania college, Gettysburg, **1,** 1844–45, p. 84–88; 105–108; 135–139.

Describes Indian summer as one of four recurrent periods in the year characterized by quiet weather, with a smoky or hazy atmosphere, and explains as a period of atmospheric equilibrium, between the seasons in which land and sea breezes, respectively, prevail.

1847.

Buys-Ballot, C. H. D.

Les changements périodiques de la température, dépendants de la nature du soleil et de la lune, mis en rapport avec le pronostic du temps, déduits d'observations néerlandaises de 1729 à 1846. Utrecht, 1847.

Includes a brief discussion of Erman's hypothesis as to effects of meteor showers in causing temperature depressions.

1849.

Azéma, E.

Sur les froids observés dans le mois de mai. Annales de la Société d'agriculture, sciences, arts et commerce du Puy, Le Puy, **14,** 1° sem., 1849, p. 287–291.

Abstract of memoir by Fournet.

Crahay, J. G.

Sur la période de froid vers le milieu du mois de mai. Bulletins de l'Académie royale de Belgique, Bruxelles, **16**, 1re partie, 1849, p. 466–472.

Observations at Maestricht, 1818–1834, and Louvain, 1835–1848, show a depression of the average temperature, with northerly winds, about the middle of May.

Fournet, J.

Note sur le froid périodique du mois de mai. Annales de la Société royale d'agriculture, Lyon, (2) **1**, 1849, p. 1-31.

Original not seen, but this appears to be the memoir abstracted at some length by Azéma, as cited above, in which Fournet attributes the recurrent cold period in May to the melting and breaking up of ice in the polar regions, and also in the rivers of Europe. According to a reference in Becquerel, "Des climats," p. 46, Fournet states that the cold period in May is observed on the coasts of America.

1851.

Barral, J. A.

Sur le froid périodique du mois de mai. Journal d'agriculture pratique, Paris, (3) **2**, 1851, p. 363–364.

Records an anecdote of Frederick the Great and the three ice saints. Presents the views of Mädler, Fournet, etc.

1853.

Sabine, Edward.

On the periodic and nonperiodic variations of the temperature at Toronto in Canada, from 1841 to 1852, inclusive. Philosophical transactions of the Royal society, London, **143**, pt. 1, 1853, p. 141–164.

Presents five-day means of temperature through the year, for Toronto, based on a 12-year record, and mentions the pentad values that "indicate in some degree a tendency to periodical recurrence." The temperature depression of May 11–13 (ice-saints) found by Mädler for Berlin is not found in the Toronto record.

1854.

Quetelet, L. A. J.

Mémoire sur les variations périodiques et non périodiques de la température, d'après les observations faites, pendant vingt ans, à l'Observatoire royal de Bruxelles. Mémoires de l'Académie royale de Belgique, Bruxelles, **28**, 1854.

Includes a conservative discussion of alleged recurrent periods of heat and cold, and gives a list of the irregularities found in the temperature curve for Brussels for the years 1833–1852.

1857.

Dove, H. W.

Über die Rückfälle der Kälte im Mai. Abhandlungen der K. Akademie der Wissenschaften, aus dem Jahre 1856, Berlin, 1857, p. 121–192.

This classic memoir on the cold period in May has been quoted by nearly all subsequent writers on the subject, and its conclusions were, for a long time, generally accepted without question. From an elaborate discussion of the records of more than 40 stations in Europe the author finds that a recurrent fall in temperature between May 8 and 13 manifests itself from Courland westward over Germany, Belgium, France, and southern England, and is espeically characteristic of central Germany. As in other well-known papers by Dove, pentad means of temperature are used in his discussion. His method is thus described by V. H. Ryd (op. cit. infra):

"Since Dove had at his disposal only a few series of observations which were sufficiently long for him to be able to use the means for the separate days, he used, to a great extent, five-day groups for his investigations. For the month of May in each separate year he has calculated the mean for the five-day period from the 1st to the 5th and from the 6th to the 10th, etc. Thus he has established normal places the 3d, 8th, 13th, 18th, 23d, and 28th of May. Let us call these values o_3, o_8, ... o_{28}. Dove then forms the differences o_8-o_3, $o_{13}-o_8$, $o_{18}-o_{13}$, etc., and when these differences get negative values, it is noted as a 'relapse.' If the true temperature curve is smooth, there will, with respect to May, where the temperature is chiefly rising, be greater probability that these differences become positive than that they become negative. Since the investigation concerns the days 11th, 12th, and 13th May, it is the differences $o_{13}-o_8$ which it depends upon, and when, f. i., Dove finds that these differences, with respect to Breslau, become negative 30 times in 66 years, this is taken as a *proof* of the existence of 'cold relapses'."

In his attempt to explain this alleged recurrence, Dove invokes his familiar hypothesis of conflicting "equatorial" and "polar" winds. His explanation, now only of historic interest, follows:

"Bestimmt man in Europa und in Nordamerika die mittlere Windesrichtung für die einzelnen Monate, so findet man, dass sie in Europa in den Wintermonaten auf die Südwestseite, in den Sommermonaten auf die Nordwestseite fällt. In Amerika findet das Entgegengesetzte statt; hier ist in den Sommermonaten die Windesrichtung mehr südwestlich, in den Wintermonaten mehr nordwestlich. Die Frühlingsmonate stellen den Wendepunkt dar; hier wird in Europa die südwestliche Windesrichtung durch eine nordwestliche verdrängt, dort die nordwestliche durch eine südwestliche. Die Polarströme, welche also im Winter vorwaltend über Amerika den Äquator zuströmen, wählen vom Frühling an ein anderes Bett über Europa hin. Dadurch erklärt sich die Häufigkeit des Einbrechens neuer Kälte in Europa durch dieselbe Ursache, wie das seltenere Hervortreten von Einbiegungen in Amerika. Die kalten Maitage bilden also ein Glied in der Kette jener grossen periodischen Veränderungen, welche sich in der Wanderung der Isothermen und in der Auflockerung der Luft im Sommer von Asien so überwiegend aussprechen. Vielleicht ist der Indianer-Sommer Amerika's das den gestrengen Herren entsprechende, in einer andern Form auftretende Phänomen des Herbstes in der neuen Welt."

Fournet, J.

Première note sur la pronostication. Annales des sciences physiques et naturelles, d'agriculture et d'industrie, Lyon, (3), **1**, 1857, p. 172–179.

Forms part of "Rapport . . . de la Commission des soies . . . 1856." The author calls attention to the general parallelism between mean annual temperature curves for three stations in different climatic regions of France; viz, Paris, Marseille, and St. Jean-de-Maurienne, and gives a list of the principal depressions. States that the period of the ice saints occurs in France about May 17–22, and that at Paris there were only two years between 1840 and 1856 in which this cold period did not prevail.

Plantamour, E.

De la température à Genève d'après vingt années d'observations (1836 à 1855). Mémoires de la Société de physique et d'histoire naturelle, Genève, **14**, 1857, p. 289–330.

Points out clearly the fallacies involved in the hypothesis that recurrent irregularities in temperature are due to the passage of meteors. Describes the winds and other meteorological conditions associated with cold periods in spring and a warm period in the mean temperature for November, but does not deal directly with the problem of recurrence on particular dates.

Sachse, K. T.

Pankratius und Servatius, ein Beitrag zur Witterungsgeschichte Dresdens. Dresdener Journal, 1857.

Not consulted.

1860.

Dove, H. W.

Über die kalten Tage im diesjährigen Mai. Monatsberichte der K. Preuss. Akademie der Wissenschaften, aus dem Jahre 1859, Berlin, 1860, p. 426–431.

Note on striking depression of temperature in May, 1859, following a mild winter. Dates of occurrence (May 11–16) given for different parts of Europe. These depressions are attributed to the wind system resulting from the contrast of temperature between the snow-covered regions of the North and the warmer regions of the South, according to the author's theory of conflicting polar and equatorial currents.

1863.

Bloxam, J. C.

On the winter which occurs in the spring of the year and on the summer which occurs in the fall of the year. Proceedings of the British meteorological society, London, **1**, 1863, p. 321–329.

"On the 21st of April the humidity is at its minimum value for the year, viz, 71.7. This is the essential fact which solves the problem: The 21st of April differs from every other day in the year in this respect; and the blackthorn winter reaches its culminating point on this day. The evaporation produced by this low degree of humidity gives rise to that peculiar feeling of cold which characterizes the season."—p. 324.

"The 9th of November may be regarded as the day on which the equinoctial summer, or St. Martin's summer, culminates, because the humidity attains a high and a maximum value on that day. Excessive humidity and consequent defective evaporation are the cause of the sensible warmth which attracts attention."—p. 327.

Fitz Roy, Robert.

The weather book: A manual of practical meteorology. London, 1863.

Cold periods in spring attributed to the fact that much atmospheric heat is used in melting the ice of circumpolar latitudes. Conversely, the liberation of latent heat in autumn, during the formation of ice in circumpolar latitudes, produces the mild weather of Indian summer.—p. 76 & 166–167.

Fonvielle, Wilfrid de.

Le petit hiver et le petit été. Presse scientifique, Paris, **2**, 1862, p. 532–537.

Not consulted.

Petit, F.

Conséquences qui paraissent devoir résulter de la comparaison des températures observées en divers lieux de la terre. Annales de l'Observatoire, Toulouse, **1,** 1863, p. 232–236.

The author finds corresponding irregularities in the annual temperature curve for Toulouse and Paris (based on five-day means for a long period of years) and attributes them to periodic meteor showers (the hypothesis first suggested by Erman, but applied by Petit to a larger number of supposedly recurrent irregularities, including warm periods and cold periods, six months apart, corresponding to the opposite nodes of the meteoric orbits in question).

1865.

Bassi, G. B.

Straordinarii abbassamenti termometrici posteriori alla metà di giugno, sospetti sulla periodica loro generalità, e congetture sulla loro derivazione. Atti, R. Istituto veneto, Venezia, **11,** 1865, p. 1163–1179.

Author finds a recurrent fall of temperature in the fourth pentad of June at various places in Italy and elsewhere in Europe. Suggests possible connection with sunspots.

Ellner, Benedikt.

Über die Rückschritte der Wärme im Monate Mai. Bamberg, 1865.

Not consulted.

Hennessy, Henry.

On the regression of temperature during the month of May. Report of the **24**th meeting of the British association for the advancement of science; held at Bath in Sept., 1864, London, 1865, p. 17 (2d pagination).

Brief abstract suggesting possible influence of dry winds from Asia and eastern Europe, causing high nocturnal radiation.

Sainte-Claire Deville, C. J.

De l'influence probable des apparitions d'astériödes sur les variations de la température de l'air. (Première note.) Comptes rendus de l'Académie des sciences, Paris, **60,** 1865, p. 577–586.

Influence of the August and November meteors on the temperature curve for Paris seems to be shown by comparing temperatures of years when these meteors were abundant with those of years in which they were scarce.

Sainte-Claire Deville, C. J.

Des perturbations périodiques de la température dans les mois de février, mai, août et novembre. (Deuxième note.) Comptes rendus de l'Académie des sciences, Paris, **60,** 1865, p. 696–710.

Same line of discussion as previous paper, but utilizes records of a number of stations in both hemispheres.

Sainte-Claire Deville, C. J.

Des perturbations périodiques de la température dans les mois de février, mai, août et novembre. (Troisième note.) Comptes rendus de l'Académie des sciences, Paris, **61,** 1865, p. 1–12; 61–65.

Develops the idea put forth in his previous notes that there is a periodic perturbation of temperature in February, May, August, and November, disclosed by comparing different groups of years, but masked in the general curve of a long series of years. This takes the form of a more or less pronounced *oscillation* of temperature rather than a departure in one direction.

Sainte-Claire Deville, C. J.

Des perturbations périodiques de la température dans les mois de février, mai, août et novembre. (Quatrième note.) Comptes rendus de l'Académie des sciences, Paris, **61,** 1865, p. 350–357.

Note on an "oscillation" in temperature and other meteorological elements in August, 1865.

1866.

Jelinek, Carl.

Über die mittlere Temperatur zu Wien, nach 90-jährigen Beobachtungen, und über die Rückfälle der Kälte im Mai. Sitzungsberichte, K. Akademie der Wissenschaften, Wien, **54,** 2 Abt., 1866, p. 671–753.

Elaborate analysis of the Vienna temperature record, and comparison with Berlin, Bern, etc. Seven irregularities are found in the annual curve at Vienna, but no cold period in May. Statistics of days with large minimum departure from the normal show three maxima in the frequency of such days during May, one of them falling on the 11th–12th. As to cold periods in May in general, the author emphasizes the fact that these have attracted special attention merely because they coincide with a critical period in the growth of vegetation.

Mitchell, Arthur.

Weather of May. Good words. London, New York, **7,** 1866, p. 336–344.

Includes an account of the cold period in May (ice saints) as described by continental meteorologists, and a corresponding period in Scotland, presenting some of the data subsequently published by Buchan. (*Vide infra,* 1869.)

Sainte-Claire Deville, C. J.

Sur les variations périodiques de la température dans les mois de février, mai, août et novembre. (Cinquième note.) Comptes rendus de l'Académie des sciences, Paris, **62,** 1866, p. 1149–1157; 1209–1213.

Deals with certain alleged correspondences between the temperatures of like dates in February, May, August, and November, as well as other apparent examples of periodicity symmetrically arranged through the year.

Sainte-Claire Deville, C. J.

Sur les variations périodiques de la température dans les mois de février, mai, août et novembre. (Sixième note.) Comptes rendus de l'Académie des sciences, Paris, **62,** 1866, p. 1298–1305.

The author finds periodic variations in barometric pressure corresponding to those which he has previously found for temperature.

Sainte-Claire Deville, C. J.

Sur les variations périodiques de la température dans les mois de février, mai, août et novembre. (Septième note.) Comptes rendus de l'Académie des sciences, Paris, **63,** 1866, p. 1030–1038.

Develops further the idea set forth in his fifth note that the mean temperature derived from the temperature of four dates of the year, equally distant from each other, either in time or in angular distance traveled by the earth in its orbit, serves to show certain recurrent fluctuations. Thus from several long temperature records (Paris, London, Berlin) it appears that there are two recurrent dips in the temperature curve, one having its center at the quadruple date January 23, April 25, July 27, October 26; the other at the quadruple date February 12, May 14, August 16, November 15.

1867.

Buchan, Alexander.

Interruptions in the regular rise and fall of temperature in the course of the year, as shown by observations made in Scotland during the past ten years, 1857–66. Journal of the Scottish meteorological society, Edinburgh, new ser., **2,** 1867–1869, p. 4–15; 41–51; 107–112.

Records of five selected stations in Scotland show five recurrent cold periods (Feb. 7–14, Apr. 11–14, May 9–14, June 29–July 4, Aug. 6–11, Nov. 6–13) and three recurrent warm periods (July 12–15, Aug. 12–15, Dec. 3–14). The cold period in April corresponds to the "borrowing days" of folklore (making allowance for the change from the Julian to the Gregorian calendar).

Sainte-Claire Deville, C. J.

Sur les variations périodiques de la temperature. (Huitième note.) Comptes rendus de l'Académie des sciences, Paris, **64,** 1867, p. 933–942.

Carrying further the method developed in his previous notes, the author averages the temperatures of 12 days spaced equally through the year, giving the temperature of a "jour dodécuple." Curves based on values of successive "jours dodécuples" show a minimum corresponding to about the 10th–14th of each month, preceded and followed by maxima; the whole constituting a sort of monthly "oscillation."

Willet, J. E.

Indian summer. American journal of science and arts, New Haven, (2) **44,** 1867, p. 340–347.

Deals chiefly with the smokiness of the atmosphere during Indian summer.

1868.

Buchan, Alexander.

Handy book of meteorology. 2d ed. Edinburgh, London, 1868.

Interruptions of temperature, p. 140–142.

Sainte-Claire Deville, C. J.

Des variations comparées de la température et de la pression atmosphériques. Comptes rendus de l'Académie des sciences, Paris, 67, 1868, p. 574–580.

Abstract. Deals with barometric fluctuations corresponding to the temperature fluctuations described in previous notes.

1869.

Quetelet, Ernest.

Mémoire sur la température de l'air à Bruxelles. Mémoires de l'Académie royale de Belgique, Bruxelles, **36,** 1869.

Discusses irregulatities in the annual temperature curve, p. 54–60, and says that their recurrence has not been established.

1870.

Dove, H. W.

Über die Zurückführung der jährlichen Temperaturcurve auf die ihr zum Grunde liegenden Bedingungen. Monatsbericht der Königl. Akademie der Wissenschaften, Berlin, 2 Juni, 1870, p. 365–379. Also published in Zeitschrift der österreichischen Gesellschaft für Meteorologie, Wien, **6**, 1871, p. 1–6.

Discusses the depression of temperature in May, and also the more marked depression in June, coinciding with the beginning of the rainy season in Germany. These are attributed to incursions of the cold polar air current, blowing from the Atlantic and from North America, where winter conditions last longer than in Europe. The northeastern seaboard of North America remains cool under the influence of floating ice from the polar regions.

1872.

Burckhardt, E.

The cold week in May. Report of the Rugby school natural history society for the 1871. Rugby, 1872, p. 25–29.

Amateurish presentation of Erman's meteorite hypothesis, without credit to Erman or other authority.

1875.

Sainte-Claire Deville, C. J.

Sur les variations ou inégalités périodiques de la température (dixième note): Période du vingtième jour dodécuple. Comptes rendus de l'Académie des sciences, Paris, **80,** 1875, p. 714–721.

Mainly a résumé of the author's previous notes, to introduce a new method of discussion.

Sainte-Claire Deville, C. J.

Sur les variations ou inégalités périodiques de la température (Onzième note); période du vingtième jour dodécuple. Novembre. Comptes rendus de l'Académie des sciences, Paris, **80,** 1875, p. 939–948; **82,** 1876, p. 540–545.

This note was intended to be the first of a series in which, instead of using the composite temperatures of "jour dodécuples," the author proposed to study, for each month in the year separately, the temperature oscillations which he believed to have their minima at regular intervals throughout the year (corresponding to different dates in the different months, on account of the irregularities of the calendar, but always falling between the 7th and the 17th), and the way in which these oscillations vary from year to year. In this note the oscillation of November is discussed, and it is shown to have occurred conspicuously in 1873 and 1874 at stations in Europe, northern Africa, and North America. The series of notes was not carried further, as the author died in 1876.

1876.

Bobynine, V.

Sur l'oscillation de la mi-novembre, observée à Nijni-Novgorod. Comptes rendus de l'Académie des sciences, Paris, **82,** 1876, p. 1108–1111.

Temperature curve for Nijni-Novgorod, 1874, and mean curve for 1870–74, shows marked oscillation in the middle of November corresponding to that found by Sainte-Claire Deville for European stations.

Hellmann, Gustav.

Ueber die Sommerregenzeit Deutschlands. Annalen der Physik und Chemie, Leipzig, **159,** 1876, p. 36–51.

A maximum of rainfall in June in northern Germany corresponds with a recurrent depression of temperature, more marked than that of the ice saints in May, due to cold northwest winds from the Atlantic, blowing toward a barometric depression formed over the warm continental interior. These cold winds also account for the maximum in rainfall.

Hinrichs, G.

Sur l'oscillation de la mi-novembre dans l'Amérique. Comptes rendus de l'Académie des sciences, Paris, **82,** 1876, p. 520–522.

Records at Iowa City, 1872–1875, show a rise of temperature, following a minimum, in mid-November, corresponding to that noted in Europe by Saint-Claire Deville. In 1874 this oscillation prevailed over a great part of Europe and the eastern United States.

Schott, Charles A.

Tables, distribution, and variations of the atmospheric temperature in the United States and some adjacent parts of America. Washington, 1876 (Smithsonian contributions to knowledge 277).

"Apparent interruptions in the regularity of the annual fluctuation," p. 183–197. Includes mean temperatures for each day of the year and curves of the mean annual march of temperature for several American stations, based on long records.

1877.

Billwiller, R.

Über die Kälterückfälle im Mai. Vierteljahresschrift der Naturforschenden Gesellschaft, Zürich, **22,** 1877, p. 207–208.

This brief paper probably contains the first attempt to explain the cold period in May on the basis of the information afforded by synoptic weather charts. The author shows that the northerly winds which produce the depression of temperature in question are due to a low-pressure area over southern or southeastern Europe, and he attributes this pressure distribution to the contrast in temperature between the northern and southern parts of the continent.

Hellmann, Gustav.

Ueber die Sommer-Regenzeit Deutschlands. Zeitschrift der österreichischen Gesellschaft für Meteorologie, Wien, **12,** 1877, p. 1–9.

Reprinted from Annalen der Physik. See above, 1876.

1880.

Scientific view of the Indian summer. Kansas City review, Kansas City, Mo., **3,** 1880, p. 486–487. From Philadelphia ledger.

Brief notice of Fitz Roy's explanation of Indian summer. (Cf. 1863.)

1881.

Assmann, Richard.

Die Nachtfröste des Monat Mai. Halle, 1885. (Reprinted, with additions, from Magdeburgischer Zeitung, June 19 & 21, 1881.)

The author presents and discusses weather maps showing the barometric conditions over Europe and the regions over which frosts occurred May 8–12, 1881. He explains the dependence of the frosts at this period upon the contrast between the thermal properties of ocean and land areas.

[Klein, H. J.]

Die Kälterückfälle im Mai. Gaea, Köln, Leipzig, **17,** 1881, p. 419–423.

A clear, popular account of the ice saints question, setting forth the views of Dove and more recent views, based on a knowledge of the circulation in cyclones.

1882.

Assmann, Richard.

Die Nachtfröste des Mai 1882. Magdeburgischer Zeitung, 1883.

Not consulted, but it is abstracted in Fortschritte der Physik, 1883. The author compares barometric conditions over Europe with the area in which frost occurred, on the dates May 5–20, for each year from 1877 to 1881. The cold period of the ice saints was quite regular in its time of occurrence, beginning over Scandinavia and thence following a course which the author describes over other parts of Europe.

Roche, Édouard.

Le climat actuel de Montpellier comparé aux observations du siècle dernier. Bulletin météorologique du Département de l'Hérault, année 1881, Montpellier, 1882, p. 37–92.

Compares the mean yearly march of temperature deduced from a long series of observations in the eighteenth century with that deduced from a modern series, and finds striking parallelism in the departures from a smooth curve, including some of the supposed recurrent irregularities found elsewhere in Europe. Includes detailed comparison with the Brussels curve.

Vincent, J.

Les hausses et les baisses thermométriques à date fixe. Ciel et terre, Bruxelles, **3**, 1882–83, p. 80–85.

The author states that the annual temperature curve based on the first half of the total record at Brussels is almost identical with that based on the second half; hence the irregularities must be real and permanent.

1883.

Bebber, W. J. van.

Die gestrengen Herren. Zeitschrift der österreichischen Gesellschaft für Meteorologie, Wien, **18,** 1883, p. 145–149.

Digest of recent papers by Assmann and Bezold with some new charts of mean isobars and temperature isanomals for the critical period of May and the month as a whole.

Bezold, Wilhelm von.

Bemerkungen zu der Abhandlung des Herrn Dr. van Bebber über "die gestrengen Herren." Zeitschrift der österreichischen Gesellschaft für Meteorologie, Wein, **18**, 1883, p. 418–423.

Deals chiefly with the question of priority in the presentation of views.

Bezold, Wilhelm von.

Die Kälterückfälle im Mai. Abhandlungen der K. bayerische Akademie der Wissenschaften, München, 2 Abt., **14**, 1883, p. 69–107.

In the years 1879–1882 the temperature depressions of May in central Europe occurred when a high-pressure area lay to the west and a low-pressure area in the east or southeast. The author proceeds to consider average conditions in May, as based on long records at European stations. In the absence of a large number of long records of pressure, he assumes that, as pointed out by Wild, the isobars in general coincide with temperature isanomals; i. e., an area of low pressure coincides with an area of maximum thermal anomaly and vice versa. Using the data computed by Dove and Jelinek, he finds that an area of maximum thermal anomaly develops over the plains of Hungary in the third pentad of May. The formation of a barometric depression in the same region and at the same period is therefore believed to be a normal feature of the climate. This would give cold northerly winds over Germany.

Hellmann, G.

Ueber den jährlichen Gang der Temperatur in Norddeutschland. Zeitschrift des K. preussischen statistischen Bureau, Jahrgang 1883.

Compares annual march of temperature at 25 stations as deduced from five-day means during a period of 35 years; also presents curve for Breslau based on a 92-year record. Besides discussing the irregularities shown in the long-year averages, the author determines for Breslau the probability, in percentage, of the occurrence of a "Kälterückfall" during each pentad from January 16 to July 29, and of a "Wärmerückfall" during each pentad from August 4 to January 10. The greatest probability of such irregularities is found in the pentads January 16–30, February 5–14, March 12–16, May 11–15, June 15–19, July 10–14, July 25–29, August 14–18, September 23–October 2, December 27–January 5. The author also shows for the various stations the greatest positive and the greatest negative irregularity that has occurred during each pentad of the year.

1884.

Billwiller, R.

Die Kälterückfälle im Mai. Zeitschrift der österreichischen Gesellschaft für Meteorologie, Wien, **19**, 1884, p. 245–246.

The problem of determining why the cold period in May is characteristic of particular dates hardly exists as there is really a wide range in the time of occurrence.

Hegyfoky, Kabos.

Die "gestrengen Herren" in Ungarn. Zeitschrift der österreichischen Gesellschaft für Meteorologie, Wien, **19**, 1884, p. 80.

Brief preliminary note, showing a slight depression in the mean temperature curve at 28 Hungarian stations in the second (not third) pentad of May.

Köppen, W.

Zur Frage der "gestrengen Herren." Zeitschrift der österreichischen Gesellschaft für Meteorologie, Wien, **19**, 1884, p. 183–185.

Points out that while Assmann, Bezold, and others have described the barometric conditions that give rise to temperature depressions in May, they have not explained why these barometric conditions tend to recur at particular dates. Suggests that it may be necessary to invoke cosmical factors.

Köppen, W., Hann, J., & Buys-Ballot, C. H. D.

Zur "Eismänner"-Frage. Zeitschrift der österreichischen Gesellschaft für Meteorologie, Wien, **19**, 1884, p. 320–325.

Letters from Köppen and Buys-Ballot and quotation from Hann, dealing with the questions, Does the barometric situation producing a cold period in May show a marked tendency to prevail on particular dates, and, if so, why?

Krankenhagen.

Vertheilung des Luftdrucks über Mittel-Europa im Juni. Meteorologische Zeitschrift, Berlin, **1**, 1884, p. 11–15.

Describes and charts the barometric conditions over Europe for each pentad of June (mean values for 1876–1883), with special reference to those which lead to a depression of temperature characteristic of the third pentad.

Krankenhagen.

Zur Charakteristik der dritten Mai-Pentade. Meteorologische Zeitschrift, Berlin, **1**, 1884, p. 371–373.

Suggests that the bad reputation of the third pentad of May (ice saints) may be due to more intense rather than more frequent frosts at that period. A note appended to this paper by W. Köppen contains a handy résumé of positive knowledge and outstanding questions concerning the May frosts.

1885.

Abercromby, Ralph.

Principles of forecasting by means of weather charts. 2d ed., London, 1885.

Discusses "recurrence," p. 65–67.

Buys Ballot, C. H. D.

The anomalies in the annual range of temperature. How to detect them. Quarterly journal of the Royal meteorological society, London, **11**, 1885, p. 104–118.

Shows that, on account of the widely different temperatures of a given date from year to year, only very long records could show conclusively the existence of recurrent anomalies.

Hromádko.

Kälterückfälle im Mai in Tabor. Zeitschrift der österreichischen Gesellschaft für Meteorologie, Wien, **20**, 1885, p. 234.

Brief note. Observations at Tabor, Bohemia, 1875–1885, show a decided preponderance of temperature depressions in the third pentad of May.

Jamin, J.

Sur le rayonnement nocturne. Comptes rendus de l'Académie des sciences, Paris, **100**, 1885, p. 1273–1276.

Discusses "la lune rousse" and "les saints de glace." Attributes prevalence of frosts at the period in question to a spring minimum of atmospheric humidity, and consequent maximum of nocturnal radiation. This article is reviewed and severely criticized in Zeit. der öst. Ges. f. Meteor, Wien, **20**, 1885, p. 269–272.

Ney, C. E.

Der vegetative Warmeverbrauch und sein Einfluss auf die Temperaturverhältnisse der Luft. Meteorologische Zeitschrift, Berlin, **2**, 1885, p. 445–451.

Author suggests that the cold period in May is due to evaporation from newly expanded foliage.

Vincent, J.

Les saints de glace. Ciel et terre, Bruxelles, (2) **1**, 1885–86, p. 145–151.

Describes barometric conditions associated with cold period in May.

1886.

Hegyfoky, Kabos.

A májushavi meteorológiai viszonyok magyarországon. Die meteorologischen Verhältnisse des Monats Mai in Ungarn. Budapest, 1886.

An elaborate study showing, among other things, that much more ample data than those cited by Bezold (1883) do *not* indicate a maximum thermal anomaly at Hungarian stations during the second pentad of May.

Hegyfoky, Kabos.

Zur Temperatur der Eismänner. Wetter, Magdeburg, **2**, 1886, p. 89–90.

Temperature record for Budapest does not show the sudden increase in thermal anomaly in the third pentad of May assumed by Bezold in his memoir of 1883.

Lancaster, A.

L'été de la Saint-Martin. Ciel et terre, Bruxelles, (2) **2**, 1886–1887, p. 447–454.

Temperature records of Belgium, France and central Germany show that the period about Nov. 11 (St. Martin's day) is, on an average, unseasonably cold rather than unseasonably warm.

Petermann, R. E.

Die Kälterückfälle im Mai. Wetter, Magdeburg, **2**, 1886, p. 105–111.

Reprint, Wiener Freie Presse.

Points out, on the basis of Hann's discussion of the Vienna temperature record (Sitzb. Wien Akad. (2) **76**, 1877, p. 685–736) that cold periods are not more likely to occur during the third pentad of May (ice saints) than at other times in the month.

1889.

Owen, Richard.

Indian summer. American meteorological journal, Ann Arbor, Mich., **6**, 1889–90, p. 392–394.

Unimportant.

Plowshare, John.

Indian summer. American meteorological journal, Ann Arbor, Mich., **6**, 1889–90, p. 530–531.

Smokiness of Indian summer has disappeared with the passing of the Indians, who formerly burned the prairie grasses every autumn.

Renou, E.

Études sur le climat de Paris. Troisième partie. Température. Annales du Bureau central météorologique de France, année 1887, I. Mémoires, Paris, 1889, p. B. 195–B. 226.

Presents yearly temperature curve for Paris based on a 130-year record, and discusses briefly the subject of recurrent irregularities (p. B. 206–207).

1892.

Schwalbe, Gustav.

Über die Maxima und Mimima der Jahreskurve der Temperatur. Inaug.-Diss. Berlin, 1892.

The author maintains that irregularities in the yearly temperature curve rarely occur in the individual years on the dates at which they are found in the average curve deduced from a many-year record.

1893.

Dufour, Ch.

Le mouvement progressif de l'abaissement de la température du milieu de mai. Bulletin de la Société vaudoise des sciences naturelles, Lausanne, (3) **29,** 1893, p. 316–320.

Although a temperature depression between May 12 and 16 is only slightly noticeable in the curves based on certain long records (Brussels, Geneva, etc.), it appears from the examination of individual years to be quite a regular feature of the climate. As pointed out in earlier literature, the cold period occurs later as we go southward, and also become less pronounced, the average date ranging from May 5 at Archangel to May 12–16 in France and Switzerland, and May 19 at Naples. Connection with the movement of icebergs is suggested.

1898.

Hennig, Richard.

Untersuchungen über die "kalten Tage" des Mai. Wetter, Berlin, **15,** 1898, p. 85–89; 106–109; 131–138; 145–156.

Shows that during 25 years the time of occurrence of a marked cold period ranged from April 30 to June 1. Discusses attendant barometric conditions.

Müttrich.

Ueber Spät-und Frühfröste. Zeitschrift für Forst- und Jagdwesen, Berlin, **30,** 1898, p. 201–233.

Discusses the frequency of late and early frosts at 16 forest meteorological stations as shown by records of from 13 to 20 years. Frosts are more frequent and more severe May 10–13 than on the days just preceding that period and on the days following.

Rijckevorsel, Elie van.

On the temperature of Europe. London, Edinburgh, and Dublin philosophical magazine and journal of science, London, (5) **45,** 1898, p. 459–467.

The author has drawn and compared mean annual temperature curves for a great number of stations, mostly in Europe, based on daily values. Although the data were extensively smoothed (by a sort of bloxaming process), and although the records varied greatly in length and pertained to widely different epochs, they show, according to the writer, a remarkable similarity. Especially within the triangle Valentia, Königsberg, Catania, the curves are said to have "identically the same irregularities." The downward slope of the ice saints is said to be apparent for Rome, Palermo, Biskra (Algeria), and Constantinople. Eastern Europe has a different type of curve from western, but the author finds a "striking similarity" between parts of the curves for Constantinople and Archangel. He suggests that some of the irregularities in these curves may be found in Asia and America, and that "we ought then to look for the explanation beyond the limits of our globe."

1899.

Bezold, Wilhelm von.

Bemerkungen zu der Abhandlung des Herrn Müttrich: "Ueber Spät- und Frühfröste." Meteorologische Zeitschrift, Wien, **16,** 1899, p. 114–117.

Taking the data discussed by Müttrich (*vide infra*) and comparing three-day periods for May, the increased frequency of frosts May 11–13 becomes even more pronounced. This cold period is less evident in the record of mean daily temperatures, owing to the frequent occurrence of high daytime temperatures on days with frost.

1900.

Barnard, R. J. A.

The annual march of temperature. London, Edinburgh, and Dublin philosophical magazine and journal of science, London, (5) **50,** 1900, p. 408–409.

Compares the annual curve of temperature for 1859–1878 at Melbourne, Australia, with the curve for 1879–1898 at the same station. Though these two halves of the total 40-year record do not show such definite agreement as Rijckevorsel has found for European stations, there are some striking similarities.

Hellmann, G.

Zur Frage der "gestrengen Herren" oder "Eismänner." Meteorologische Zeitschrift, Wien, **17,** 1900 p. 333–335.

The tradition of the ice saints antedates the introduction of the Gregorian calendar. Hence there has been some confusion as to the period to which it applies. It also dates from a time when only a few days in the month were dedicated to particular saints, so that the traditional weather of a certain saint's day (e. g., St. Servatius) must be interpreted broadly as belonging to a considerable part of the month.

Hergesell, H.

Ergebnisse der internationalen Ballonfahrten. Meteorologische Zeitschrift, Wien, **17,** 1900, p. 1–28.

Balloon observations at various places in Europe on May 13, 1897, show (p. 16) that the temperature distribution characteristic of the ice saints was even more pronounced at high levels than near the surface. The contrast between low temperatures in the west and high in the east and northeast was found up to more than 10,000 meters.

Kremser, V.

Beiträge zur Frage der Kalterückfälle im Mai. Meteorologische Zeitschrift, Wien, **17,** 1900, p. 209–214.

Records at three German stations show a pronounced maximum of frost temperatures, during *certain decades*, for the three-day period May 11–13, both in the mean of the whole decade and in most of the individual years. Records extending back many years, however, do not show the same feature, but show a regular decrease in frequency of frosts from the beginning to the end of May. Hence the cold period of the ice saints either is not a permanent feature of the climate or else it is a periodic one. In the latter case it might have occurred so persistently during certain series of years as to attract public attention and give rise to the belief in its recurrence.

Rudel, K.

Zur Frage des Auftretens der Eismänner in Bayern. Meteorologische Zeitschrift, Wien, **17,** 1900, p. 373–375.

Records of Bavarian stations do not show that frosts are especially frequent on the dates of the ice saints.

1901

Lancaster, A.

Les refroidissements périodiques de mai. Ciel et terre, Bruxelles, **22,** 1901–02, p. 205–209; **23,** 1902–03, p. 111–119.

The annual temperature curve at Brussels and also at several other places (Edinburgh, Berlin, etc.) shows a number of cool periods in May as pronounced as that of the ice saints, or more so, indicating a more or less regular "rhythm", of short period, in the march of temperature.

MacDowall, A. B.

Recurrence of cold and warm weeks. Symons's meteorological magazine, London, **36,** 1901, p. 21.

Points out some weekly and monthly recurrences in the Greenwich records.

1902.

Abbe, Cleveland.

Indian summer. Science, New York, new ser., **15,** 1902, p. 793.

Brief note. Deals with name only.

Abercromby, Ralph.

Weather. A popular exposition of the nature of weather changes from day to day. London, 1902.

Recurrent types of weather, p. 312–317.

Lancaster, A.

Un intéressant phénomène. Les refroidissements du milieu de juin depuis vingt ans. Ciel et terre, Bruxelles, **23,** 1902–03, p. 231–233. Note complémentaire, p. 311–313.

Cold period, with frost, toward the middle of June occurred frequently in recent years of the Brussels record, but seldom in early years.

"Note complémentaire" contains further details regarding the relative frequency of cold periods in May shown by old and recent records for Brussels. Points out a corresponding change in the barometric curve.

Luizet, M.

Sur les perturbations périodiques de la température en juin et en décembre. Ciel et terre, Bruxelles, **23,** 1902–03, p. 415–419.

Calls attention to some recurrent irregularities in the temperature curve for June and December at Lyon. A note by Lancaster appended to this article shows resemblance between Lyon and Brussels curves.

Marten, Wilhelm.

Über die Kälterückfälle im Juni. Inaug.-Diss. Berlin, 1902. Also published as Abhandlungen des K. preuss. meteorologischen Instituts, Berlin, **2,** no. 3, 1902.

A fall in temperature in the second decade of June is found to be characteristic of a region of Europe extending from England and France over western Russia to the Black Sea. It advances from northwest to southeast, increasing in intensity. It is due to the transportation of masses of cold air in connection with a characteristic distribution of pressure. The recurrence of these pressure conditions can not yet be fully explained, but the explanation is probably to be sought in the general circulation of the atmosphere, coupled with the thermal contrasts between land and water.

Matthews, Albert.

The term Indian summer. U. S. Weather bureau, Monthly weather review, Washington, **30,** 1902, p. 19–28; 69–79.

This valuable memoir discusses the history of the term "Indian summer" but deals only incidentally with the phenomenon itself.

Murat, I. St.

Clima dilei de dece maiŭ. Analele, Academiei Române, Bucuresci, (2) **25,** 1902.

Study of the weather of May 10 (a Roumanian national holiday) during 25 years. The author finds that while depressions of temperature occur in Roumania on the days of the ice saints (May 10–12) they are not a more characteristic phenomenon than depressions occurring on other dates in May. Cold weather tends to occur at intervals of seven days in that month.

1903.

Barbé, G.

Sur la question des saints de glace des 11–13 mai. Annuaire de la Société météorologique de France, Paris, **51,** 1903, p. 137–142.

Mainly a résumé of publications by Müttrich, Bezold, Kremser, Gautier and Duaime, etc., with some remarks on the correspondance of dates between the Julian and Gregorian calendars, in relation to the ice saints.

Gautier, Raoul, & Duaime, Henri.

Quelques chiffres relatifs aux saints de glace. Archives des sciences physiques et naturelles, Genève, (4) **15,** 1903, p. 545–557.

Discussion of a 75-year temperature record for Geneva shows a wide variation in the time of occurrence of temperature depressions during May. Certain groups of years suggest recurrence; but the mean of the whole record shows a regular rise of temperature through the month. The general conclusion agrees with that reached by Kremser (1900) in his discussion of German records.

Maurer, H.

Zur Frage der "gestrengen Herren" oder "Eismänner." Meteorologische Zeitschrift, Wien, **20,** 1903, p. 176–178.

Date of St. Servatius day (one of the ice saints) as affected by the change from the Julian to the Gregorian calendar.

Moureaux, Th.

Sur les refroidissements et les réchauffements de la température en juin. Annuaire de la Société météorologique de France, Paris, **51,** 1903, p. 117–118.

Points out contradictory evidence as to occurrence of warm and cold periods in June obtained from different periods of years at Paris and Brussels.

Les refroidissements périodiques de mai et de juin. Ciel et terre, Bruxelles, **24,** 1903–04, p. 166–168.

Abstract of some recent literature.

1904.

Friesenhof, Gregor.

Die Temperatur-Depressionen im Monate Mai, zugleich ein Beitrag zur Frage der Eismännerperiode und des Urban. Meteorologische Zeitschrift, Wien, **21,** 1904, p. 232–235.

The record of daily minimum temperatures at the Neutratal observatory (Hungary) shows that there are six periods in May characterized by temperature depressions, the largest number of low temperatures occurring May 1–3 and the next largest May 12–15 (ice saints).

Indian summer. Scientific American, New York, **91,** 1904, p. 330.

Includes unscientific and erroneous explanations.

Moureaux, T.

Résumé de trente années d'observations météorologiques á l'observatoire du Parc Saint-Maur (1874–1903). Annuaire de la Société météorologique de France, Paris, **52,** 1904, p. 233–242.

Brief notice of irregularities found in the annual temperature curve, p. 241–242.

1905.

Jochimsen, C.

Die Kälterückfälle im Mai. Wetter, Berlin, **22,** 1905, p. 256–259.

Temperature record at Neumünster 1898–1905 shows wide range in time of occurrence of cold periods during May.

Rijckevorsel, Elie van.

Konstant auftretende secundäre Maxima und Minima in dem jährlichen Verlauf der meteorologischen Erscheinungen. Abt. 1–11. Rotterdam, 1905–1913; Utrecht, 1913–1917. (Abt. 9–11 published as K. nederlandsch meteorologisch instituut, No. 102, Mededeelingen en Verhandelingen, 16,17, 22.)

The author develops in this large work the ideas set forth in his memoir of 1898, cited above. In the first two parts, both published in 1905, he presents tabulated data and curves showing the annual march of temperature at a great number of stations throughout the world. Certain other meteorological and nonmeteorological statistics are presented, including sunspot data. The temperature records are of various length, some more than 100 years, and the mean daily temperatures used in constructing the curves are smoothed (bloxamed). As in his previous paper, he finds that the secondary maxima and minima, having periods of a few days, are essentially world-wide phenomena, pointing to a cosmical origin. On this assumption he constructs what he calls "normal curves;" one for a European area, one for each hemisphere, etc. In order to make the secondary maxima and minima more apparent, he eliminates from these normal curves the annual temperature wave, so that the curves become irregular horizontal lines. Finally, from the normal curves of the two hemispheres he eliminates further an alleged semiannual wave, and then combines these curves to obtain a normal curve for the world as a whole. In subsequent parts of the work, which is still in course of publication, he has dealt in an analogous way with barometric pressure, rainfall, vital statistics, sunspots, and terrestrial magnetism.

1906.

Kremser, V.

Fünfzigjährige Pentadenmittel der Lufttemperatur für Norddeutschland. K. Preussisches meteorologisches Institut, Ergebnisse der Beobachtungen an den Stationen II. und III. Ordnung im Jahre 1900, zugleich Deutsches meteorologisches Jahrbuch für 1900, Berlin, 1906, p. xvii–xxiv.

Discusses the annual march of temperature at stations in northern Germany as based on 50-year records and compares results with those previously found by Hellmann in his discussion of 35-year records. Some of the irregularities previously found disappear in the mean of the longer record. The cold period in June persists, but chiefly at inland stations.

Millot, C.

L'été de la Saint-Martin à Nancy. Bulletin de la Société des sciences, Nancy, (3) **7,** 1906, p. 135–137. Also published (except for tables) in Annuaire de la Société météorologique de France, Paris, **54,** 1906, p. 237–241.

"En résumé, l'été de la Saint-Martin considéré comme un regain temporaire de chaleur existe réellement à Nancy, quoique assez peu accentué; mais le froid de la Toussaint qui le précède contribue à en exagérer l'importance par contraste."

1907.

Fassig, O. L.

Report on the climate and weather of Baltimore and vicinity. Maryland weather service, Baltimore, **2,** 1907.

Irregularities in the annual temperature curve discussed on p. 80–82. As to the temperature in May, it is stated that "there is a distinct rise from the 9th to the 12th in place of the European fall" and a similar rise is found in the temperature curves for Washington, Norfolk, Nashville, and Columbus. "A probable explanation of this phenomenon may be found in a periodic recurrence at this time of an area of high barometric pressure over the South Atlantic States, or an extension westward of the permanent area of high pressure over the North Atlantic in latitude of about 30° in conjunction with the development of a barometric depression in the Mississippi Valley."—p. 81.

Hörmann, Ludwig von.

Wetterherren und Wetterfrauen in den Alpen. Zeitschrift des deutschen und österreichischen Alpenvereins, München, **38,** 1907, p. 93–114.

Includes folklore relating to the ice saints.

Jochimsen, C.

Die Kälterückfälle im Juni mit besonderer Berücksichtigung der Provinz Posen. Landwirthschaftliches Centralblatt für Deutschland, Berlin, **35,** 1907, p. 237–239.

Not consulted.

1908.

Hecker, Alfred.

Die gestrengen Herren. Mitteilung aus dem Institut für Bodenlehre und Pflanzenbau der K. landwirtschaftl. Akademie Bonn-Poppeldorf. Landwirtschaftliche Jahrbücher, Berlin, **37,** 1908, p. 711–729.

After a comprehensive history of previous investigations, the author gives an elaborate analysis of a 60-year temperature record for Bonn, in which daily means are given for various groups of years, etc. The general conclusion is that while temperature depressions occur in May almost any year, they are not especially characteristic of the dates of the ice saints.

Lancaster, A.

Les "saints de glace" en 1907. Ciel et terre. Bruxelles, **28,** 1907-1908, p. 179–180.

Abnormally warm weather occurred in Belgium on the days of the ice saints in 1907.

Luizet, M.

Sur les saints de glace et l'été de Saint-Martin. Association française pour l'avancement des sciences, Compte rendu de la 36me session, Reims, 1907, Paris, 1908, p. 256–260.

A comparison of temperature records at Lyon, during May and November, for the period 1851–1878 and the period 1881–1906, showing a striking *dissimilarity* in the curves in both cases. Combining the early and recent records tends largely to smooth out the irregularities.

Musy.

Les retours de froid au milieu de mai. Bulletin de la Société des sciences naturelles. Fribourg, **16,** 1908, p. 62–65.

Not consulted.

1909.

Jochimsen, C.

Die gestrengen Herren oder die Eisheiligen des Mai mit besonderer Berücksichtigung der Provinz Brandenburg. Landbote, Prenzlau, **30,** 1909, p. 405–410.

Not consulted.

Mossman, R. C.

The cold period of May in arctic and antarctic regions, with special reference to 1903. Symons's meteorological magazine, London. **44,** 1909, p. 1–6.

The author states that the cold period in May occurs in both hemispheres, including the arctic and antarctic regions. It was well marked in the antarctic during the expeditions of 1899, 1902, and 1903. "It is specially marked in Argentina and Chile in the southern, and over the greater part of Europe in the northern hemisphere. It is absent or but feebly developed in S. America south of 40° S. At all places where it occurs it is associated with high pressure, and the anticyclonic conditions relative to the normal are most pronounced in Antarctica. At places where it does not occur cyclonic conditions prevail. This cold period is followed by a great rise of temperature in the northern, and a slight rise in the southern hemisphere, which is most abnormal, occurring, as it does, within four weeks of the winter solstice in the southern hemisphere. So regular a feature is the cold period of May at the South Orkneys that in only one year (1906) since the station was established in March, 1903, has it failed to make its appearance."—p. 3.

Not only this particular interruption of temperature, says the author, but warm and cold periods in general are synchronous in both hemispheres, and are probably due to interrelations between the northern and southern centers of action.

1910.

Gautier, Raoul.

Sur le retour de froid en juin. Verhandlungen der schweizerischen naturforschenden Gesellschaft, Basel, **93,** 1910, p. 328.

Brief abstract. Records of recent years at Geneva and Grand St. Bernard show a marked cold period in the second decade of June, but it it not found in the records of earlier years.

1911.

Gautier, Raoul, & Duaime, Henri.

Les retours de froid en juin à Genève et au Grand Saint-Bernard. Archives des sciences physiques et naturelles, Genève (4) **31,** 1911, p. 497–508.

The recurrent cold period in June is found in the Geneva record since the middle of the nineteenth century, but not, in general, in the earlier records, running back to 1796. Nearly similar results for Grand St. Bernard. Hence the phenomenon seems to undergo a secular change.

Lehmann, Artur.

Altweibersommer. Die Wärmerückfälle des Herbstes in Mitteleuropa. Landwirtschaftliche Jahrbücher, Zeitschrift für wissenschaftliche Landwirtschaft, Berlin, **41,** 1911, p. 57–129.

The leading account of the warm period or periods in Europe corresponding to the Indian summer of America (known under about 25 names, of which the author gives a list). The folklore of the subject is discussed, and an account is also given of the gossamer which floats in the air in the autumn and bears the same name as the period in question (*Altweibersommer*). The weather and barometric conditions over Europe in September and October are described, year by year, from 1890 to 1908. The author finds that weather of the Indian summer type is most frequent over central Europe in the fifty-fifth pentad of the year (Sept. 28–Oct. 2), and is associated with a widespread area of high barometric pressure over the continent, somewhat east of its center, bringing mild southeasterly winds to the region mentioned, together with clear skies, favoring strong insolation during the day. These conditions may last from a few days to three or four weeks.

Morrow, Josiah.

Indian summer. U. S. Weather bureau. Monthly weather review, Washington, **39,** 1911, p. 469–470.

Deals with name only.

1912.

Meissner, Otto.

Die Kälte- und Wärmeperioden des Jahres, erläutert an den Potsdamer meteorologischen Beobachtungen. Wetter, Berlin. **29,** 1912, p. 81–84; 97–109; 158–162; 176–183.

In a 16-year record for Potsdam the author finds 10 cold periods and 7 warm periods. He gives the average dates and duration of each, attendant winds and other conditions, etc. The most reliable of these unseasonable spells is a period of cold, rainy weather in September, which occurred in every year of the record; average dates, September 8–16. It never began later than the 16th. This is one of the very few meteorological publications in which the dog days are mentioned as a feature of the annual temperature curve.

1913.

Almstedt, Karl.

Die Kälterückfälle im Mai und Juni. Inaug.-Diss. Göttingen, 1913.

Comprehensive study of the depressions in May and June found in the mean annual temperature curves of several European stations and of the mean barometric and wind conditions pertaining to the same periods. With respect to the supposed recurrent cold period in June, the author maintains that this is not a brief depression, but rather the beginning of a period extending through the summer in which, on account of monsoon winds, the temperatures are lower than they would be without these winds.

Indian summer at home and abroad. Scientific American, New York, **109,** 1913, p. 379.

Brief account, with notice of work by Lehmann.

"From a meteorological point of view, in Europe as in America, there are probably several 'Indian summers' in some years, while occasionally a year may have none. In other words, 'Indian summer' is merely a convenient designation for the most delightful of all types of autumn weather."

Rudel, Kaspar.

Juni-Kälterückfälle. Wetter, Berlin. **30,** 1913, p. 185–187.

List of marked cold periods in June at Nürnberg from 1879 to 1913.

Thraen, August.

Die Wärmedepressionen im Mai und ihr Einfluss auf den Niederschlag. Meteorologische Zeitschrift, Braunschweig, **30,** 1913, p. 380–386.

Records of the amount and frequency of rainfall at four German stations, differing considerably in altitude, exposure, etc., show the marked influence of the cold periods in May defined by Friesenhof (1904), one of these being the period of the ice saints.

1914.

Almstedt, K.

Die Kälterückfälle im Mai und Juni. Meteorologische Zeitschrift, Braunschweig. **31,** 1914, p. 426–433.

Abstract of his dissertation of 1913, above cited.

Flammarion, Camille.

L'été de la Saint-Martin. Bulletin de la Société astronomique de France, Paris, **28,** 1914, p. 487–490.

Analysis of temperature records for Juvisy (near Paris), 1901–1914, showing that the temperature does not tend to rise at the time of the November meteor shower (Leonids), November 14–17. There is also no recurrent rise of temperature on November 11 (St. Martin's day). Suggests that pictures of St. Martin sharing his cloak with a poor man may have given rise to the tradition concerning the weather of St. Martin's day.

Meissner, Otto.

Existieren die "Eisheiligen"? Wetter, Berlin, **31,** 1914, p. 176–179.

Records for Swinemünde, on the Baltic coast, 1898–1910, show a maximum frequency of NE. winds on May 10 (ice saints) and May 20–25 (little ice saints).

Schmidt, Albert.

Die Anomalien des jährlichen Temperaturganges und ihre Ursachen. Jahrbücher des Nassauischen Vereins für Naturkunde, Wiesbaden, **67,** 1914.

The author points out that temperature irregularities in the spring, when the "normal" temperature curve has a steep ascent, and in autumn, when it has a steep descent, are more likely to be smoothed out in the mean curve deduced from a long record than the irregularities of summer and winter, where the "normal" curve is approximately horizontal. This accounts for the greater prominence of the cold period in June as compared with those of April and May. He also shows that it is illogical to speak merely of abnormal *falls* of temperature in spring and abnormal *rises* of temperature in autumn, ignoring rises in spring and falls in autumn. The cause of the irregularities is found chiefly in the seasonal (semiannual) changes in great centers of action, and the irregularities are therefore most pronounced at the transition periods (spring and autumn) and over central Europe (lying between oceanic and continental regions of climate).

1915.

Hann, Julius von.

Lehrbuch der Meteorologie. 3d ed., Leipzig, 1915.

See pages 102–104. Handy digest, with references to the principal literature.

Talman, C. F.

Indian summer. U. S. Weather bureau, Monthly weather review, Washington, **43,** 1915, p. 44–45.

Deals with name only.

1916.

Ware, H. E.

Notes on the term Indian summer. Publications of the Colonial society of Massachusetts, Cambridge, Mass., **18,** 1916, p. 123–130.

Deals with name only.

Reed, W. G.

Indian summer and Plimsoll's mark. U. S. Weather bureau, Monthly weather review, Washington, **44,** 1916, p. 575.

Deals with name only.

1917.

Arctowski, Henryk.

Normal anomalies of the mean annual temperature variation. London, Edinburgh and Dublin philosophical magazine and journal of science, London, (6) **33,** 1917, p. 487–495.

The author finds that the irregularities in typical curves showing the annual march of temperature at stations throughout the world are steplike, as if the station had been shifted to a warmer or colder climate, or they are changes to a curve of larger or smaller amplitude, corresponding, respectively, to a continental or a marine climate. He also points out the "intimate relationship between very far distant stations," and concludes "that in a comparative study of the anomalies of the annual temperature variation, Teisserenc de Bort's conception of the great centres of action of atmospheric circulation will find an extensive application, because, although at present it would be premature to try to explain why it is that some changes of phase may occur simultaneously in Arctic and Antarctic regions, or in North America and Siberia, it seems impossible to conceive such correlations without supposing some relationship with the exchange of pressure between the seasonal and permanent centres of action."—p. 495.

Ryd, V. H.

On the computation of meteorological observations. Kjøbenhavn, 1917. (Publikationer fra det Danske meteorologiske Institut. Meddelelser Nr. 3.)

Chapter 7. Secondary minima and maxima in the annual variation of the temperature, p. 40–45. Criticizes the views of Dove and others as to the reality of the supposed recurrent cold period in May and other recurrent irregularities. If these are not real features of the climate they will gradually disappear as the period of observation grows longer. A comparison between the summer temperature curve at Copenhagen based on a record of 124 years and one based on a period of 25 years shows how the anomalies tend to be smoothed out in the longer record. The author also shows that the annual march of temperature may be accurately represented by a curve based on five-day means, according to a method of adjustment which he describes.

Forbes, W. E.

Ice saints. Annals of the Astronomical observatory of Harvard college, **83,** pt. 1, Cambridge, Mass., 1917, p. 53–59.

Analysis of a temperature record kept at New Bedford, Mass., 1813–1905, shows no definite recurrence of heat or cold about May 10. An instructive diagram shows the variability from year to year of the mean temperature for each date from May 7 to May 15.

RAINSTORM OF AUGUST 13–14, 1919, ON MARYLAND-DELAWARE PENINSULA.

By A. H. THIESSEN, Meteorologist.

[Dated: Baltimore, Md., Sept. 24, 1919.]

A rain and wind storm of unusual severity occurred on Wednesday, August 13–14, 1919, over the entire Maryland-Delaware Peninsula, resulting in immense damage to agriculture, roads, and bridges, and was the indirect cause of injury and death to several persons.

The morning weather map of August 13, 1919, showed a disturbance central off the Virginia coast moving northward, and the forecaster at the Central Office, Washington, D. C., ordered southeast storm warnings for the Atlantic coast from Delaware Breakwater to Boston. Rain began on the north Virginia coast about midnight of the 12th, and as the storm moved north the rain became general by 8 a. m. over the entire peninsula. At times it fell in torrents, but gradually diminished in intensity toward the end of the afternoon of the 13th, when it ended in the southern portion of the peninsula, but continued until early morning of the 14th in the northern portion. Heavy gales attended this rain, and the following maximum velocities were reported: 50 miles an hour at Norfolk, Va.; 60 on the beach at Atlantic City, N. J.; 35 at Cape May, N. J.; and 62 at Cape Henry, Va.

It is the general opinion that the destruction of property and crops was made easy due to the previous wet condition of the land, which was true, as very little loss of substantial buildings was reported, although numerous outbuildings and large shade and fruit trees were blown down or torn up by the roots, indicating that the anchoring was poor. The damage resulting from this storm was enormous and was variously estimated, but two or three million dollars would probably cover all material damage.

All standing crops were blown or beaten down to a greater or less extent. Corn was first blown down one way, and then when the wind changed was blown the other way and broken off, the tassels were whipped off and the blades shredded. Blossoms on late crops were blown from the plants, especially beans and tomatoes. Fruit trees were stripped of pears, peaches, and apples. Fields of tomatoes, cabbages, and potatoes were flooded, and truck in general was damaged by the wind and excessive rain. Wheat in the shock suffered, as it could not be moved, due to the miry condition of the ground. Potatoes just planted were a total loss. Many shade and fruit trees were split or blown to earth. Losses of cows, pigs, and poultry due to drowning were not inconsiderable.

Houses were injured by the wind driving in rain and thus damaging ceilings and walls. Milldams gave way and besides being a loss in themselves caused additional loss

by adding small floods, making washouts all the more easy. Telegraph and telephone lines were either blown down or were broken by trees falling against them. Traffic was suspended on the railroads for two days in places, due to weakening of the roadbed, dangerous bridges, and lack of communication. Roads were badly washed, wooden bridges were carried away, and concrete bridges were greatly weakened and some collapsed.

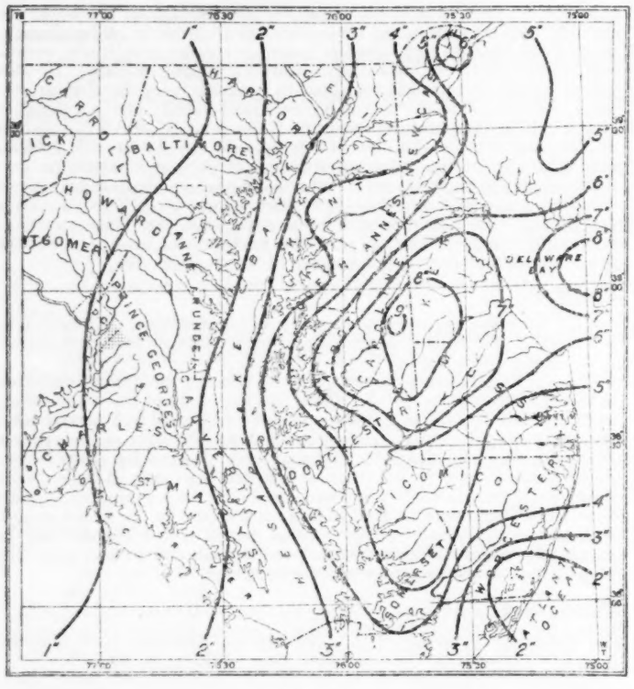


FIG. 1.

A washout near Denton, Md., caused the wreck of a work train, in which one person was killed and four injured. Two men were drowned on two barges which broke away from their moorings and sank in Delaware Bay. Another man was drowned by the foundering of a dredge at Port Penn, Del.

The accompanying chart shows the precipitation from this storm. It appears to have been greatest in the central portion of the peninsula, while very large amounts fell in northern Delaware and southern New Jersey.

WATERSPOUTS ON LAKE ERIE, AUGUST 19, 1919.

W. J. Willoughby, master of the steamer *Fleetwood*, reports having seen two waterspouts on August 19, 3 or 4 miles from the Buffalo breakwater. The *Fleetwood*, westward bound, left Buffalo at 7 a. m. of that date. When about a mile out from the breakwater a heavy rain squall was encountered. The squall (west wind) lasted about 20 minutes. "When it cleared away I noticed south of us about a mile some mist like steam on the water. [I] took the glasses to look at it but could not make much out of it. Shortly after this I noticed a thin spiral cloud drop down and connect itself with the white mist that looked like steam. It got bigger until it looked like the trunk of a large tree and I recognized it as a waterspout. Another formed about one-half mile away from the first. I noticed them for some time when we lost sight of them. They were the first I have ever seen on the Lakes, and I have been sailing for about 30 years."

HOT SQUALL AT MIAMI, FLA., MAY 6, 1917.

A wind squall, attended by unusually pronounced pressure fluctuations and a remarkable rise in temperature, occurred shortly after 6 a. m. An extreme wind velocity of 52 miles per hour from the southwest was recorded at 6:21 a. m. The temperature rose from 71° (F.) at 5 a. m. to 88° at about 6:25 a. m., the last 10° of the rise occurring within a period of a few minutes. It

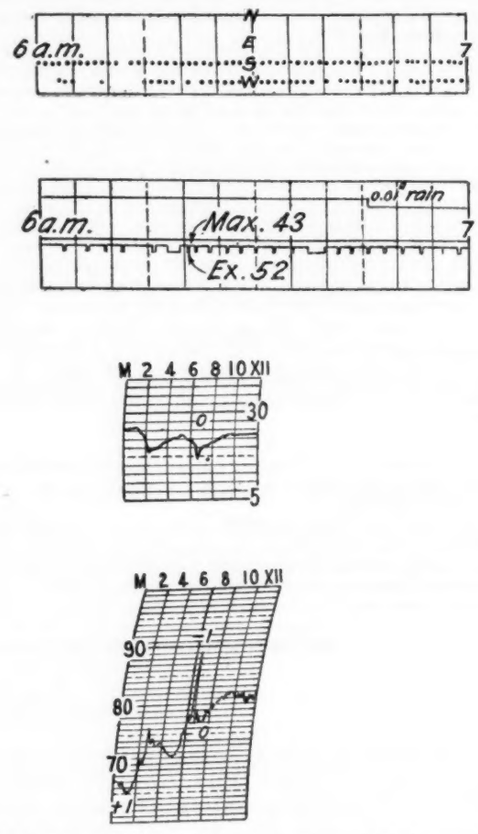


FIG. 1.—Tracings from wind, temperature, and pressure records, Miami, Fla., May 6, 1917.

then as suddenly fell to 77°. The temperature of 88° was considerably higher than had ever been recorded at this station at so early an hour. See fig. 1.

A thunderstorm occurred at Miami during the night of the 5th–6th, but it ended between 1 and 2 a. m. The barograph trace shows that there were abnormal pressure fluctuations following the thunderstorm and preceding the squall, indicating decidedly unstable conditions. An examination of the weather map of May 6 shows a moderate depression off the southeast Florida coast, forming part of a trough of low pressure extending along the Atlantic coast to southern New England. This, of course, was a favorable condition for thunder squalls, and thunderstorms were reported on that morning from all Weather Bureau stations on the Florida and east Gulf coasts, with the exception of Jacksonville.

There was no rain in connection with the hot squall, and none immediately preceding or following it. All regular and cooperative stations in southern Florida, however, reported rain on the 6th, the amounts being generally light. I have no means of ascertaining the time of occurrence of these rains. The sky at Miami during the early morning and the forenoon of the 6th was covered by St. Cu. clouds.

The sudden and phenomenal rise in temperature *must* have been caused by air that had been forced downward and heated adiabatically, but why the sudden and decided fall in pressure, instead of a rise, as occurs with the forward and downward rush of air from a thunderstorm? It is difficult to reconcile a strong descensional wind, such as must have occurred, with a simultaneously falling barometer.

The fall of pressure with this *hot* squall, however, corresponds to the rise in pressure attending *cold* squalls. I have never known the outrush of air from a thunderstorm to fail to lower the temperature, regardless of whether the storm was or was not attended by rain.—*R. W. Gray.*

A HILLTOP FOEHN.

On the summit of Great Blue Hill (195 m. high) near Boston; Mass., May 6, 1913, immediately following a thunderstorm, in fact, three-quarters of an hour before the thunder ceased, a northwest wind of moderate force brought an almost instantaneous rise of temperature from 61° to 78° F., and an equally rapid fall in humidity from 100 per cent down to 20 per cent. These conditions persisted with minor interruptions (when temporary shifts of wind to the southwest put the temperature down 10° or so) for four hours, 10:20 p. m.–2:20 a. m. This extraordinary free-air foehn took place exactly in the center of a weak cyclone. At the base station, 118 meters below the summit of the hill, the maximum temperature was but 68°F.—*Charles F. Brooks.*

RELATION OF CLOUDS TO WEATHER IN CENTRAL OHIO.

By HOWARD H. MARTIN, Observer.

[Dated: Weather Bureau, Columbus, Ohio, Aug. 25, 1919.]

SYNOPSIS.—It is the object of this paper to present as fully as possible the relation existing between the appearance of the various cloud forms and the subsequent changes in weather and temperature. To this end, a total of 5,037 observations at Columbus, Ohio, have been considered, covering a period of 10 years, 1909–1918, inclusive. A comparison of the prognostic values of cloud indications as observed at Columbus with those determined for San Francisco (1) will give the reader, at a glance, the salient differences existing between the marine and the continental types of climate, as shown by varying cloud forms.

Cirrus.—It is well known that cirrus attains the greatest altitude and the greatest velocity of all cloud forms. It has been regarded by tradition and adage as the first indication of approaching storm. With regard to this, Mr. Palmer says:

> Though cirrus and cirro-stratus clouds are apparently at times associated with anticyclones, they are typical accompaniments of cyclones. If a longitudinal section were made through the vertical axis of a typical cyclone and parallel to its direction of progression, the cirrus and cirro-stratus sheet forming the topmost portion would extend forward from the center a long distance and backward a shorter distance. In the sequence of events which usually precede cyclonic precipitation, clouds of this kind are ordinarily the first sign, often occurring many hours before the barometer begins to fall or before any other indication of the approaching storm makes its appearance.

TABLE 1.—*Weather conditions following cirrus clouds.*

Clouds moving from—	Number of cases.	Precipitation followed—			Temperature changed within 24 hours.		
		Within 12 hours.	Within 24 hours.	Within 48 hours.	Less than 6°.	6° or more warmer.	6° or more colder.
April to September:		*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
N	32	0	0	13	100	0	0
NE	23	0	52	54	46	54	0
E	2						
SE	1						
S	1						
SW	14	0	0	0	22	0	78
W	94	12	45	56	53	23	24
NW	44	29	29	29	57	0	43
For season	211	12	33	46	56	18	26
October to March:							
N	12	0	0	83	25	75	0
NE	11						
E	23	52	52	61	39	61	0
SE	11						
S	12	0	0	0	25	0	75
SW	23	61	61	61	18	43	39
W	34	65	70	70	71	0	29
NW	64	18	52	70	22	78	0
For season	190	32	45	58	47	44	19
For the year	401	21	38	50	48	30	22

[1] A. H. Palmer, Clouds and their significance in local weather forecasting. MONTHLY WEATHER REVIEW, 1918, (46): 406–413.

Table 1 is a summary of the weather conditions following cirrus clouds observed at Columbus during the 10 years of observation. All cirrus clouds covering 0.1 or more of sky at time of observation are included in the table which embraces 401 cases. The weather following is computed in terms of the per cent of frequency of occurrence. As Mr. Palmer points out in his paper, high clouds can necessarily be observed only when unobscured by lower clouds, but it does not seem probable that, even were it possible to secure data of these clouds when so obscured, the final results would be altered to any extent.

It will be noted from Table 1 that cirrus clouds moving from a westerly or northwesterly direction are far more indicative of precipitation than from any other quadrants, excepting perhaps the northeast, where for a limited number of observations a rather high prognostic value was obtained, during the summer months, and from the north, during the winter months. Subsequent temperature changes exceeding 6° were more frequently positive during the winter months and negative during the summer, although for the year as a whole they were well divided. With the exception of movements from the directions noted above, cirrus was found to have a low prognostic value for Columbus. For a limited number of observations, (26) during the 10 years of cirrus moving at high velocity 76 per cent were followed by precipitation within 48 hours, whereas with no apparent movement 33 observations gave a prognostic value of only 26 per cent.

Cirro-stratus.—Table 2 reveals the fact that cirro-stratus, present at what might aptly be termed the secondary stage of cyclonic approach, is, when moving from a westerly direction, a rain prognostic of comparatively high value, especially during the winter months.

During these months, too, the appearance of such clouds is usually followed within 24 hours by a marked temperature change, exceeding 6°, a change of this character following 64 per cent of the 151 obsevations, regardless of cloud direction. When, during the winter, cirro-stratus approached from the southwest the value was considerably enhanced, 87 per cent of the 33 observations being followed by a pronounced change. Dur-

ing the summer months the changes were equably divided, with the negative slightly in excess, while during the winter the positive changes were predominant. When moving from a westerly direction, cirro-stratus may be relied upon to precede precipitation by 48 hours or less approximately seven times out of a possible 10, but when no direction is observed, its prognostic value is lessened to practically nil. Of 33 observations of this character, but one was followed by rain or snow within 48 hours. When the apparent velocity is greater than usual, the prognostic value is increased correspondingly. Of 57 observations at an unusual velocity, 88 per cent were followed by precipitation within 48 hours, regardless of direction.

TABLE 2.—*Weather conditions following cirro-stratus clouds.*

Clouds moving from—	Number of cases.	Precipitation followed—			Temperature changed within 24 hours.		
		Within 12 hours.	Within 24 hours.	Within 48 hours.	Less than 6°.	6° or more warmer.	6° or more colder.
April to September:		*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
NE	12	75	75	75	.....	.....	.....
E	1	.....	.....	.....	.....	.....	.....
SE	38	26	78	78	83	17	0
SW	147	5	58	73	65	0	35
W	232	10	58	67	58	23	19
NW	130	16	48	48	44	40	16
For the season	560	13	58	61	58	21	21
October to March:							
SW	33	0	66	66	13	54	33
W	90	0	77	78	37	43	20
NW	28	0	93	93	64	0	36
For season	151	0	78	79	36	38	26
For year	711	10	61	64	54	24	22

Alto-stratus.—Table 3 presents the relation of the appearance of alto-stratus to subsequent meteorological conditions.

TABLE 3.—*Weather conditions following alto-stratus clouds.*

Clouds moving from—	Number of cases.	Precipitation followed—			Temperature changed within 24 hours.		
		Within 12 hours.	Within 24 hours.	Within 48 hours.	Less than 6°.	6° or more warmer.	6° or more colder.
April to September:		*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
NE	42	0	52	52	76	24	0
E	22	0	82	82	100	0	0
SE	33	30	30	68	70	30	0
SW	144	56	92	92	40	15	45
W	268	42	60	68	74	18	8
NW	152	20	38	38	72	6	22
For season	661	35	60	65	67	15	18
October to March:							
N	10	.....	.....	.....	.....	.....	.....
NE	10	.....	.....	.....	.....	.....	.....
S	9	.....	.....	.....	.....	.....	.....
SW	43	46	92	92	45	0	55
W	124	20	75	95	16	55	29
NW	51	0	46	50	40	60	0
For season:	247	17	66	79	36	41	23
For year	908	30	62	69	59	22	19

Of the alto-stratus cloud, Mr. Palmer says:

As indicated by its name, alto-stratus is a high stratiform cloud. Though not so high as cirro-stratus, it is usually much thicker and unlike the latter, it frequently is the source of considerable precipitatoin . . . In the usual sequence of events between the appearance of the first cirrus streamers and precipitation it marks an intermediate stage, most frequently following alto-cumulus and immediately preceding the lower clouds which give the precipitation. If a map were drawn to show the prevailing cloud visible in all parts of a typical cyclone, alto-stratus would form a broad ring nearly concentric with the isobars and immediately surrounding the area where rain was falling. This ring would be broad at the front and narrow at the rear.

It is especially to be noted from the table above that an unusually high prognostic value attaches itself to the movement of alto-stratus from the southwest during the summer months, while an even higher value is obtained during the winter months from the west and southwest. The movements of alto-stratus from an easterly direction was recorded at 97 observations, 62 per cent of which were followed by precipitation within 48 hours. This easterly movement, while unusual, accompanies the passage of a cyclone up the Atlantic coast and occurs during the winter months only.

Temperature changes in excess of 6° followed 64 per cent of the observations during the winter, regardless of direction, and when the cloud movement was from the west 84 per cent of the observations were so followed. The changes were positive during the winter and slightly negative during the summer, and were generally unimportant, only 41 per cent of all observations being so followed.

Cirro-cumulus and Alto-cumulus.—Since cirro-cumuli were recorded but a relatively few times during the period of 10 years in question, all observations of that cloud form were combined with those of alto-cumuli, the combined results being shown in Table 4.

TABLE 4.—*Weather conditions following cirro-cumulus and alto-cumulus clouds.*

Clouds moving from—	Number of cases.	Precipitation followed—			Temperature changed within 24 hours.		
		Within 12 hours.	Within 24 hours.	Within 48 hours.	Less than 6°.	6° or more warmer.	6° or more colder.
April to September:		*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
SE	14	0	70	70	34	66	0
SW	92	43	65	79	65	11	24
W	64	16	35	51	100	0	0
NW	40	50	74	74	100	0	0
For the season	210	35	62	74	79	10	11
October to March:							
SW	71	14	76	92	29	28	43
W	134	26	76	98	16	34	50
NW	90	23	60	74	16	60	24
For the season	295	22	69	89	20	40	40
For the year	505	26	65	82	45	27	28

As a rain prognostic, alto-cumulus from a westerly direction holds a high percentage during the winter months, 85 per cent of such observations being followed by precipitation within 48 hours.

Temperature changes exceeding 6° followed 79 per cent of all observations during the winter months, movements from the west and southwest being favored with a percentage of 84 per cent. The changes were equally divided between positive and negative during the winter, and bore a slight excess to positive during the summer, but, on the whole, were unimportant, with the exceptions previously noted.

Table 5 shows that the observation of cumulus was confined to the summer months, but 18 instances of winter cumuli being noted.

Of cumulus clouds, Palmer says:

True cumulus clouds are more often associated with the borders of the cyclone than with its center. * * * In certain places * * * cumulus clouds are a daily occurrence, due partly to excessive local heat-

ing and partly to the absence of strong horizontal movement. Whenever observed, cumulus clouds are of particular interest because of the information they give concerning the wind velocity aloft. Though the base of a cumulus cloud is ordinarily found in a region of comparatively calm air, the summit of the cloud often extends into a region of comparatively calm air, the summit of the cloud often extends into a region of swiftly moving air. Under these conditions the cloud leans forward. Sometimes the increase in wind velocity with increase of height is so rapid that the cloud "loses its head"; that is, the top portion is detached from and blown in advance of its base.

TABLE 5.—*Weather conditions following cumulus clouds.*

Clouds moving from—	Number of cases.	Precipitation followed—			Temperature changed within 24 hours.		
		Within 12 hours.	Within 24 hours.	Within 48 hours.	Less than 6°.	6° or more warmer.	6° or more colder.
April to September:		*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
N	11	.....	.....	.....	.....	.....	.....
SW	42	71	97	97	52	0	48
W	102	41	60	70	68	10	22
NW	40	81	81	81	75	25	0
For the season	195	52	68	74	69	10	21
October to March:							
E	9	.....	.....	.....	.....	.....	.....
W	9	.....	.....	.....	.....	.....	.....
For the Season	18	.....	.....	.....	.....	.....	.....
For the Year	213	.....	.....	.....	.....	.....	.....

The presence of true cumulus is apparently an excellent rain prognostic, especially when the movement is from the southwest, 97 per cent of such observations being followed by rain within 24 hours. All directions considered, it bears probably the highest prognostic value of any cloud form hitherto discussed. Its relation to temperature is apparently unimportant, a change of 6° or more following but 31 per cent of the observations.

Strato-cumulus.—Of the strato-cumulus, Palmer says in part:

Formed only at low levels, its constituent particles are usually in liquid form, though the combination of two or more particles [of moisture] may produce snowflakes when the temperature is sufficiently low. Of itself, this cloud does not give heavy or widespread precipitation. Throughout most of the United States it gives only light showers in summer and snow flurries in winter. However, it is closely associated with the true nimbus cloud of the typical cyclone and is usually the last cloud observed immediately before and the first cloud seen immediately after long-continued precipitation.

TABLE 6.—*Weather conditions following strato-cumulus clouds.*

Clouds moving from—	Number of cases.	Precipitation followed—			Temperature changed within 24 hours.		
		Within 12 hours.	Within 24 hours.	Within 48 hours.	Less than 6°.	6° or more warmer.	6° or more colder.
April to September:		*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
N	82	15	42	42	.....	28	14
NE	33	0	0	0	.....	.....	.....
E	14	0	0	0	.....	.....	.....
SE	103	70	89	89	80	20	0
S	20	90	90	90	30	0	70
SW	232	66	87	87	51	4	45
W	309	33	55	61	63	6	31
NW	208	31	51	57	57	16	27
For season	1,001	44	64	68	59	11	30
October to March:							
N	33	37	37	97	67	33	0
NE	11	0	0	92	23	0	77
E	12	75	75	75	30	0	70
SE	23	49	52	56	100	0	0
S	34	90	90	93	8	0	92
SW	182	67	91	93	12	20	68
W	190	43	58	81	42	21	37
NW	148	36	44	60	37	28	35
For season	633	49	62	78	35	20	45
For the year	1,634	45	62	70	51	14	35

Of all the cloud forms observed at Columbus, strato-cumulus has been observed with the greatest degree of frequency, 1,634 observations having been made in 10 years. Of this number, it was observed 1,001 times in summer and 633 times in winter. When moving from the southwest, it has a high prognostic value, being followed by precipitation within 48 hours 87 per cent of times observed during the summer and 93 per cent during the winter. For a limited number of observations, movement from the south may be considered of fairly high prognostic value, also.

It is to be noted that when the cloud movement is southwest a negative temperature change follows its appearance within 24 hours, during the summer months, 45 per cent of times observed. In the winter, under the same conditions, this negative change occurs with even greater frequency, 68 per cent of the observations being so followed. Temperature changes following the appearance of strato-cumulus lean perceptibly toward the negative: 582 of the 818 observations followed by any change preceded temperature falls in excess of 6°.

As has been pointed out by Palmer—

Certain kinds of clouds are almost invariably associated with certain kinds of weather, and at times when the distribution of barometric pressure and temperature and wind velocities and directions are such as to create doubt in the mind of the forecaster, the kind and amount of clouds, and the direction in which they are moving will help him to decide upon the proper forecast to issue.

This is brought out very forcibly by glancing back over the tables and ascertaining the kind and direction of certain clouds most frequently associated with subsequent precipitation. For instance, during the winter months, the presence of alto-stratus moving from a southwesterly direction could be considered a reliable rain prognostic, since 92 per cent of all observations of movement from that direction were followed by precipitation within 24 hours; alto-cumulus from a westerly point, 98 per cent of such observations being followed by rain within 48 hours; cumulus from the southwest during the summer months, 97 per cent of such observations preceding rainfall by 24 hours or less; and strato-cumulus from the southwest at any time of the year, 89 per cent of such observations occurring within 24 hours of precipitation. It is probable that the direction of the surface wind bears an important relation to precipitation, but at this time no study has been given to this subject. It is obviously true, however, that movement from the southwest appears to be most frequently associated with subsequent precipitation with practically all cloud forms, and especially so with the lower clouds.

Palmer has found that in San Francisco the significance of cloud appearance increases as the height of the cloud decreases; that this significance varies greatly with direction; that for the higher clouds those moving from the southwest are most frequently followed by rain; that for the intermediate levels, those from the south are so followed; while for the lowest levels southeast is the direction of greatest significance.

In comparison, it may be said that in Ohio this significance also varies greatly with direction; that for the higher clouds, those moving from the west are most frequently followed by rain; that for the intermediate levels, those from the southwest are so followed; while for the lowest levels, southwest and south are the directions of greatest significance.

There appears to exist no doubt that clouds are a most important factor in practical weather forecasting, and too much stress can not be laid upon their most careful observation, the direction being an element too often ignored by hasty or careless observers. In smoky cities, and on

dark mornings, it is especially difficult to ascertain either the direction or kind of cloud, and many observers hazard a guess rather than wait to determine the true classification, yet it should be remembered that observations of this character are often of less value than no observation at all and from a scientific standpoint are vicious in the extreme. Every careful, conscientious cloud observation and every well-determined direction of cloud movement is a distinct contribution to science and in this is its own reward.

FROST CONTROL AND RELATED FACTORS.

By J. C. WHITTEN, Professor of Pomology, University of California.

[Dated: February, 1919.]

Heretofore we have thought of protecting plants from cold only by direct methods, such as covering or sheltering the plants or by orchard heating, to raise the temperature of the surrounding atmosphere. This conception was based upon the accepted belief that a given kind of plant inherits a given degree of hardiness; that there is a "critical temperature," above which the plant will live without injury and below which the plant will be injured or even die. Certain kinds of plants are notably hardy or resistant to injury from cold. Others are notably tender and subject to injury even in relatively mild climates.

We now know that while the above factors are true, in part, they do not explain the whole truth in determining the resistance of a plant to cold or to drought or to heat or to any other environmental influence that may favor or oppose the health and safety of the plant. To emphasize this statement we only need to call attention to the fact that a given variety of fruit trees may safely endure low winter temperatures while it is dormant or at rest; that it may be injured by a mere frost after it has started growth in spring; and that a sudden frost may kill it after it has gotten into the accelerated growth of the warmer summer.

The state or condition of a plant at a given time, its degree of ripeness and rest, or its degree of activity and growth governs largely how much cold or other unfavorable influence the tree may safely endure.

Studies made at the Missouri Experiment Station show that normally the sap of a fruit tree is least concentrated (contains the least sugar and digested plant food) during the period of rapid length growth in spring and early summer. Sap becomes more and more concentrated after length growth ceases. The supply of plant food reserves becomes greatest as the tree goes into winter condition.

The earlier a tree finishes its length growth the more concentrated its sap becomes and the more abundant its supply of plant food reserves. The more concentrated its sap the more cold the tree will stand either in winter or during spring frosts. In one plot, peach trees which had continued rank length growth until frost in autumn had all their flowers killed on a night the following spring at a temperature of 27°. The following night the temperature dropped to 22°. An adjoining plot of trees, which ceased length growth early, but which maintained healthy mature leaves until frost, endured this lower temperature safely without injury to their blossoms.

The merits of the new system of pruning, now being advocated, are better understood in the light of the above facts. The prominent feature of the former standard system of pruning is that the trees are severely headed back each winter. As a result, rank new growth is stimulated at the top of the cut-back branches. This rank, tender growth continues to lengthen and to make new leaves throughout practically the entire summer. This prevents early storage of plant food reserves and concentration of sap in the tree.

In the new system of pruning, the main limbs are established as early as possible. Once they are established they are not subsequently headed back. They are pruned by thinning out surplus limbs. Length growth ceases early. The tree early attains a concentrated sap and stores plant food reserves. These slow-growing limbs and leaves become firm in texture and evaporate but little water. There is no rank succulent upper limbs to rob or shade out the parts below. The leaves are not likely to draw water out of the fruit in time of drought. The concentrated sap gives up its water less readily. Such trees will endure more spring frost or more drought, due to their better ripened or perfected tissue and their more concentrated sap.

Judicious summer pruning consists of the removal of any surplus tender, succulent water sprouts that are growing where they are not wanted. Any permanent limbs that are continuing length growth too late may be checked in their growth by clipping them back. Dead, broken, or diseased parts should be removed.

So long as trees can secure ample water to supply their leaves, it is not desirable to reduce the leaf surface more than to check length growth of late-growing limbs. If drought is severe and trees are evaporating more water than can be supplied, evaporating surface may be reduced by judiciously removing the more tender, succulent parts, which are least needed as permanent limbs of the tree. Tender, soft, new leaves evaporate many times more water than older, firmer leaves that formed early in the season. The older, firmer leaves, if healthy, and which take on a dark green color, are more serviceable in the elaboration of plant food reserves.

WHITEWASH THE TRUNKS OF YOUNG TREES TO PREVENT SUN SCALD.

The trunks of young trees should be whitewashed as soon as they are planted in the orchard to prevent sun scald and the drying out of the buds and growing layer. Whitewashing the trunks of young trees should be kept up each winter for the first three to five years after the young trees are planted. Exposed trunks or bare main limbs of older trees are also protected from sun scald if kept whitewashed.

Sunscald is most severe in winter, even though the injury may not be noticeable until summer. The coloring matter in the bark of trees absorbs heat enough from the sun's rays on sunny days to raise the temperature of the growing layer to from 15° to 25° (F.) above the temperature of the air. This renders the cells of the growing layer and buds, especially on the sunny side of the tree, turgid, active, and tender.

As the sun goes down at night, the temperature of the tree falls promptly to the temperature of the air, which may be to freezing or even below. This wide fluctuation of temperature between day and night injures the growing layer and buds.

Whitewashing the exposed trunks reflects the sun's rays, keeping the tree at or a little below atmospheric temperature. This keeps the tissues of the tree dormant, even during a sunny day, and not subject to injury when the temperature drops gradually at night.

Heretofore it was thought that sun scald occurs during the hot dry days of summer. A study of the temperature of the trunks and twigs of the trees during summer shows that this is not the case.

The upward passage of cool water from the roots and its evaporation from the twigs and leaves cools the parts of the tree above ground. During a hot, dry day in summer the trunk and twigs of a tree are usually cooled to a temperature from 15° to 20° below the temperature of the air. This cooling is most marked adjacent to green leaves, which evaporate much water. It is least marked on long, bare trunks and main limbs which have no twigs and leaves to evaporate water. This emphasizes the desirability of preserving rosettes of leaves and short fruiting twigs all up and down the trunks and main limbs to shade and cool the parts where sun scald usually occurs. It also emphasizes the desirability of low-headed trees. These leaves also digest plant food to nourish the limbs, trunks, and roots, maintaining a thicker, healthier annual ring of new sap wood.

If sun scald begins on the south side of the trunk and main limbs in winter, it can continue during summer. Winter sun scald dries out the tissues and opposes the development of sap wood and green leafy twigs on the exposed parts. Cool sap is not readily carried through these dried and injured parts so they are less cooled during hot summer days.

A good whitewash which will stick may be made as follows: Slack 15 pounds of lime, in which 2 pounds of salt and 3 pounds of sulphur are sifted while the lime is slacking. The heat of the slacking lime acts on the salt and sulphur so as to form a wash which will stick. Add water to make a thick whitewash and apply to the tree trunks by means of a spray pump or a brush.

Whitewashing the trunks of young trees or sunscalded parts of older trees is desirable, especially in winter. It is not necessary on older trees with thick bark and which possess twigs that shade the limbs.

ABSTRACTS, REVIEWS, AND NOTES.

BRITISH RAINFALL ORGANIZATION.

On July 25, 1919, in accordance with an arrangement approved by H. M. Treasury, the responsibility for the management of the British rainfall organization was transferred by the trustees of the organization to the director of the meteorological office. In accordance with the terms of the transfer, the publication of *British Rainfall* will be continued and *Symons's Meteorological Magazine* is also assured of continuance in association with the *Circular* of the Meteorological Office.

The news of the retirement of Dr. H. R. Mill on account of his impaired eyesight was recently announced, and has been received with much regret by all who are interested in the study of rainfall. The 19 years of his connection with the organization have shown continuous development of the study of the subject on scientific lines.—*Meteorological Office Circular, 39, Sept. 1, 1919, p. 1.*

THE "METEOROLOGICAL GLOSSARY" OF THE BRITISH METEOROLOGICAL OFFICE.[1]

The title of this exceedingly useful compend is somewhat misleading. It is really a pocket encyclopædia of meteorology and kindred sciences. The name "glossary" suggests that one may find here definitions of at least all the more usual words and expressions pertaining to meteorology, but such is not the case. No meteorological glossary worthy of the name has yet been published. The lists of definitions found in Bartholomew's "Atlas of Meteorology" and Marriott's "Hints to Meteorological Observers" supply even less adequately than the new publication of the Meteorological Office the lexicographic information needed by meteorologists.

Only about 400 terms or subjects are treated in the work under review. Taking the letter "A" as a sample of the book in general, we note the omission of *afterglow, air-drainage, Alpenglow, anchor-ice, anomaly, antitrade, arched squall,* and *atmometer* (*atmidometer*), besides hosts of rarer expressions belonging to the language of meteorology, such as *advection, aelloscope, Æolus, aerobioscope, aeroclinoscope, aeroconiscope, aeroscope, aerotherm, æthrioscope, air-tester, All-Hallown summer, allobar, ammil,* etc.

The size of the meteorological vocabulary is realized by very few meteorologists. The present reviewer has labored desultorily during the past 10 years in gathering material toward a comprehensive meteorological dictionary, including in its scope both scientific and nonscientific terms relating to weather and climate, and although upward of 10,000 terms have already been listed the enumeration is still fragmentary.

While the glossary of the Meteorological Office contains many definitions, it is primarily a series of articles, some of them several pages in length, on topics that either are directly meteorological or have some important meteorological application. Under the latter head we find several physical and mathematical articles of rather exceptional interest to the meteorologist, to whom they supply information not easily obtainable elsewhere in a form so convenient for his use. There are, for example, excellent brief discussions of harmonic analysis, correlation, heat, entropy, and buoyancy.

The articles on purely meteorological subjects represent the fruit of the latest investigations, and are therefore a valuable and indispensable supplement to all existing textbooks of meteorology. Aerological subjects are well represented, and there are succinct presentations of recent views and data relating to such topics as the audibility of explosions, visibility, gusts, eddies, and gradients.

The definitions of terms are generally valid and accurate, though a few are open to improvement. We regret to find that British meteorologists persist in using the word *isopleth* (p. 168) as a synonym of *isogram*, the generic name for the "iso-" lines. Ever since the former term was introduced by Ch. Vogler, in 1877, it has been applied almost exclusively, outside of recent British writings, to an isogram drawn on a system of coordinates at least one of which indicates *time* rather than space. Isograms of this class are described by Hann, in his "Lehrbuch der Meteorologie," 3d ed., p. 91, and in this connection he says: "Der Name 'Isoplethen,' der eigentlich Kurven gleicher Zahlenwerte beteutet, was ja auch z. B. die Isothermen usw. sind, *wird nur auf diese Darstellungsmethode angewendet.*" (Our italics.) The important

[1] Great Britain. Meteorological office. Meteorological glossary. 4th issue. London. 1918. 358 p. 24°. (M. O. 225 il.)

point is, of course, that the group of isograms drawn on time coordinates is left without a specific name if the term *isopleth* is applied to isograms in general.

On page 78 we note a curious attempt to distinguish between a "*dekad*" and a decade. We have not previously encountered the term *dekad*, but it is obviously a truncated form of the German word *Dekade*, which is precisely equivalent in meaning and application to the English word *decade*. Any group of 10 is a decade, whether it be of days, years, or what not. Decades of days were a feature of the French republican calendar, and have been used to some extent in meteorology (e. g., in the "Dekadenberichte" of the Deutsche Seewarte), though not so frequently as pentads.

The definition of *cumulo-stratus* on page 77 should be rewritten or omitted. "The name given to a certain combination of cloud forms which is no longer used in the international classification" is a sentence that, besides inviting the animadversion of grammarians, does not help us to identify the clouds in question; and the reference "See *Clouds*" leads nowhere, as this term is not mentioned under "Clouds." The history of the name *cumulo-stratus* is traced at some length by Clayton in the Annals of Harvard College Observatory, volume 30, part 4, page 328–329.—*C. F. Talman.*

SOME OFFICIAL PUBLICATIONS OF THE BRITISH METEOROLOGICAL OFFICE.

[From Met'l. Off. Circs. 29, 30 and 37, 1919.]

Professional Notes.—A new series of publications has been started recently with the general title *Professional Notes.*

These notes are printed on sheets uniform with this [Met'l Off.] Circular [8 vo.] so that they are more convenient for handling and for binding than the *Geophysical Memoirs.*

Professional Notes, No. 1. **ON THE INTERRELATION OF WIND DIRECTION AND CLOUD AMOUNT AT RICHMOND (KEW OBSERVATORY.)** *By David Brunt.*

This note was published "confidentially" in April, 1918. The aim of the investigation was to discover, if possible, whether a relationship, which would be of aid in forecasting cloud amount, could be established between the direction of the wind and the cloud amount, and further to determine the frequency of the clearing of the sky at night with winds of different directions. For this purpose tables of frequencies of different cloud amounts for different wind directions have been compiled for the hours of 10h., 16h., and 22h. for each month, the observations of wind and cloud at Kew Observatory for the years 1899–1913 being used. In the discussion of these tables the following points have been brought out: Firstly, that the months group themselves into two distinct types, winter and summer, between which are two months of transition, April and October; secondly, that SW. and W. winds are by far the most prevalent, forming 50 per cent of the total; thirdly, that the tables for 22h. show a marked increase of clear skies for all months, but the most striking cases of diurnal variation are shown by E. winds in August, SW. winds from July to October, and W. winds especially during August and November.

Each of the wind directions (eight points) have been discussed separately from the point of view of cloud amount, and it was noticed that winds with an easterly component give very cloudy skies at Richmond. In order to get some indication as to how far this is due to London smoke being carried by such winds tables for Greenwich for January and July have been compiled. Greenwich appears to be less cloudy on the whole than Richmond, but the differences are not sufficiently great to be important.

Professional Notes, No. 2. **NOTES ON EXAMPLES OF KATABATIC WIND IN THE VALLEY OF THE UPPER THAMES AT THE AEROLOGICAL OBSERVATORY OF THE METEOROLOGICAL OFFICE AT BENSON, OXON.** *By E. V. Newnham.*

This is a short discussion on the night breeze which occurs in settled fine weather at Benson and which blows from the direction of the Chiltern Hills. From the records of the tube anemometer the writer chooses nine examples of this type of wind for discussion and shows that it must be classified as a "katabatic" wind representing the downward flow of air cooled by radiation on the slopes of the hills. Anemograms for six of these cases are reproduced as halftone illustrations. For the nine selected nights hourly means of the wind velocity, temperature, and gustiness are worked out and the results plotted.

Professional Notes, No. 3. **INCIDENCE OF FOG IN LONDON ON JANUARY 31, 1918.** *By C. E. P. Brooks.*

This is an account of the development and distribution of the fog which prevailed in the London area during the three days January 30 to February 1, 1918. From various personal experiences and accounts of the disorganization of traffic, the writer has compiled a map of the fog intensity, assigning to the various districts figures 0 to 5 on the scale of the London Fog Inquiry. This map shows that the thick fog was chiefly confined to the low ground in the valley of the Thames upstream from Fulham and to the tributary valleys of the Beverly Brook and the River Wandle, the high ground on the north and south being relatively clear.

Particulars of the pressure, wind and temperature for the three days so far as they are known to the meteorological office are given. The maps show a high-pressure area over southeast England, France, and Germany, with light easterly airs. These conditions at the surface appear to have been accompanied by a wind from 10 to 20 miles per hour from the south up above and by a marked temperature inversion. The writer describes the fog as a "typical radiation fog of anticyclonic weather," and suggests that the hills on either side contributed a gravitational flow of cold air sweeping the fog from the higher ground into the valley of the Thames and preventing any tendency to overflow north and south.

Professional Notes, No. 4. **UPPER AIR TEMPERATURES AT MARTLESHAM HEATH, FEBRUARY, 1917, to JANUARY, 1918.** *W. F. Stacey.*

The temperature observations of the upper air made in aeroplanes by the testing squadron of the R. F. C. stationed at Martlesham Heath, Ipswich, have been utilized in the preparation of this note.

Professionce Notes, No. 5. **ON THE USE OF THE NORMAL CURVE OF ERRORS IN CLASSIFYING OBSERVATIONS IN METEOROLOGY.** *By Capt. E. H. Chapman.*

In this paper the theory of statistics is applied to the discussion of such questions as the interpretation of the terms "usual," "not unusual," and "exceptional" with reference to various meteorological phenomena.

Professional Notes, No. 6. **THE VARIATION OF WIND VELOICITY WITH HEIGHT.** *By Capt E. H. Chapman.*

The author puts forward an empirical rule that the speed of the wind in the lower layers is a linear function of the logarithm of the height.

Professional Notes, No. 7. **"THE CLIMATE OF NORTH-WEST RUSSIA."**

This was prepared for the use of the British forces acting on the Murman coast. The general climate is discussed for the district extending from the Arctic Ocean on the north to Petrograd and the Gulf of Finland on the south, and from the Swedish frontier on the west to 45° E. on the east. It deals with the dates of the thawing and freezing of the rivers. The temperature of the upper air is discussed, and other meteorological information is given.

SMITHSONIAN METEOROLOGICAL TABLES.

[Fourth revised edition. Preface reprinted.]

The original edition of the Smithsonian Meteorological Tables was issued in 1893, and revised editions were published in 1896, 1897, and 1907. A fourth revised edition is here presented, which has been prepared under the direction of Prof. Charles F. Marvin, Chief of the United States Weather Bureau, assisted by Prof. Herbert H. Kimball. They have had at their disposal numerous notes left by the late Prof. Cleveland Abbe, and have consulted with officials of the United States Bureau of Standards and of other Government bureaus relative to the value of certain physical constants that have entered into the calculation of the tables.

All errata thus far detected in the earlier editions have here been corrected. New vapor pressure tables, derived from the latest experimental values by means of a modification of Van der Waals interpolation formula, devised by Prof. Marvin, have been introduced.* The table of relative acceleration of gravity at different latitudes has been recomputed from a new equation based upon the latest investigations of the United States Coast and Geodetic Survey. These values have been employed in

*A discussion of these is being prepared for a later issue of the REVIEW.

reducing barometric readings to the standard value of gravity adopted by the International Bureau of Weights and Measures, supplementing a table that has been introduced for directly reducing barometer readings from the value of gravity at the place of observation to its standard value.

The new values of vapor pressure and of gravity acceleration thus obtained, together with a recent and more accurate determination of the density of mercury, have called for an extensive revision of numerous other tables, and especially of those for the reduction of psychrometric observations, and the barometrical tables.

Among the new tables added are those for converting barometric inches and barometric millimeters into millibars, for determining heights from pressures expressed in dynamic units, tables of gradient winds, and tables giving the duration of astronomical and civil twilight, and the transmission percentages of radiation through moist air.

The tables of International Meteorological Symbols, of Cloud Classification, of the Beaufort Scale of Winds, of the Beaufort Weather Notation, and the List of Meteorological Stations, are among those extensively revised.

Tables for reducing barometric readings to sea level, and tables of logarithms of numbers, of natural sines and cosines, of tangents and cotangents, and for dividing by 28, 29, and 31, with a few others have been omitted from this edition.

BEN NEVIS OBSERVATORY REOPENED.

[Reprinted from Aeronautics (London), July, 1919, p. 43.]

The Air Ministry, states the Observer, is about to take over the observatory erected on the summit of Ben Nevis 35 years ago by the Scottish Meteorological Society, and utilize it in connection with their system of weather forecasting for aerial purposes. This will be an important addition to the chain of meteorological stations already established, as by its means continuous observations of the physics of the upper air will be possible at an elevation of well over 4,000 feet above sea level.

For 20 years the Scottish Meteorological Society maintained the Ben Nevis Observatory, and daily records were obtained for comparison with the sea-level records at Fort William Observatory at the foot of the mountain. But its upkeep was a heavy drain on the society's resources, necessitating an expenditure of £1,000 a year, toward which the Government contributed only £100, as a grant from the meteorological committee. About the year 1900 the society intimated that it would be compelled to close the observatory; but, fortunately, Mr. Mackay Bernard, of Dunsinnon, came forward and promised £500 annually for four years. The society therefore decided to continue the observatory in the hope that the Government would follow the lead of continental nations—German especially—and make itself responsible for this high-level meteorological observatory.

But instead of additional Government assistance, in 1904 the grant from the meteorological committee was withdrawn, and the Scottish Meteorological Society, unable to guarantee the cost of the institution, in that year, withdrew the staff, and the observatory closed. Since then the buildings have fallen into a sad state of repair, and last year a party who ascended Ben Nevis reported that the observatory was falling to pieces.

Now that the Air Ministry has taken over the observatory it will probably be entirely rebuilt and equipped with modern instruments. Meteorologists know very little about the upper air, especially the prevailing winds and currents, and their relation to the surface winds. These are some of the things that must be scientifically investigated before aviation will be as safe and reliable as ocean traveling, and if observatories similar to that on Ben Nevis were established by the Air Ministry on all the elevated peaks of the British Isles it would hasten forward the solution of the problems of the upper air, for which we now mainly rely on the automatic records brought to earth by ballons-sondes.

MOUNTAIN METEOROLOGICAL STATIONS IN EUROPE.

[Reprinted from Scientific American, New York, Aug. 16, 1919, p. 153.]

Mountain meteorological stations in Europe, as they were before the war, are described in a recent number of Naturwissenschaften by Prof. F. Klengel. Of the 21,500 stations in operation in various European countries, 660 were more than 1,000 meters above sea level, about 150 more than 1,500 meters, 44 more than 2,000 meters, 8 more than 2,500 meters, and 1, the Sonnblick Observatory, above 3,000 meters. The observatory of the Sonnblick (3,106 meters) is the highest meteorological station in Europe that is in operation the year round, but there are still higher stations that remain open a few months each year; e. g., the Vallot Observatory on Mont Blanc (4,358 meters) and the Regina Margherita Observatory on Monte Rosa (4,560 meters). These very lofty establishments are inaccessible in winter, but are used for various investigations in summer. The above enumeration of lofty stations does not include a large number of seasonal snow gages, or so-called "totalizers," which have been installed on an extensive scale in the Alps by the Swiss Meteorological Service. These gages are visited once a year, when the gage is emptied and its contents measured.

THE HARVARD STATION IN JAMAICA.

By WILLIAM H. PICKERING.

[Review. Annals of the Harvard College Observatory, vol. 82, No. 1, pp. 37.]

In consideration of the condition upon which property, to the value of $230,000, was left to the Harvard College Observatory by the will of the late Uriah A. Boyden, for the purpose of furthering astronomical research "at such elevation as to be free, as far as practicable, from the impediments to accurate observations which occur in the observatories now existing, owing to atmospheric influences," three expeditions were sent to Jamaica.[1] It was decided to locate the observatory at Mandeville (elevation, 2,100 feet), as the place most satisfactorily fulfilling the conditions of the bequest; yet for the value of astronomers and other interested parties, a series of meteorological observations, such as were pertinent to the astronomical work, were carried out. Thus certain observations, usually made at meteorological stations were omitted, while others, which are quite unsual were made.

Temperature.—In the thermometric observations the equipment consisted of standard maximum and minimum thermometers and a Richard thermograph. These were not exposed in a shelter, but upon the porch of a house facing the east. The only ill effect, from a thermometric standpoint, was due to the sun shining upon

[1] Cf. "The meteorological activities of the late Prof. Edward C. Pickering," by R. De C. Ward, MONTHLY WEATHER REVIEW, April, 1919, 47: 241-242.

the thermograph in the early hours; but this was not serious because the temperature at that time was, for the purpose, not used, and the consequent "cusp" in the curve afforded a record of the clearness of the sunrise.

The temperatures as observed at Mandeville are quite interesting. The highest temperature recorded during four years 1912–1916 was 89.2° F. The lowest recorded temperature was 56.1° F. On four days only did the thermometer fail to reach 70° F. The warmest night, August 12, 1915, the thermometer did not fall below 74.6° F. The mean daily variation from the normal for four years is 12.4°.

When the thermometer goes above 85° it is considered hot, and when it drops below 60° it is considered cold.

Wind.—Wind observations were not made automatically as no anemometer or wind recording apparatus was carried. General observations showed, however, that the prevailing wind comes from the ESE. While hurricanes occasionally pass near the station, the most severe was the one of November, 1912, when the maximum wind velocity was estimated at 55 miles per hour. It was believed that owing to the broken and hilly nature of the country about Mandeville, this figure is probably correct.

Rainfall.—Rainfall is very heavy. The mean of 28 years is 87.84 inches. The minima of the rainfall seem to occur in February and July. It always rains hard, and most generally comes in sharp, short showers. So sharp is the edge of a shower that it has rained on one side of the house and not at all on the other. On the average it rains 182 days each year. The heaviest rainfall recorded for 24 hours was 9.90 inches. Attention is called to the fact that the rainfall minima for the island seem to have a certain relation to the sunspot period. It was concluded that there was a diminishing of rainfall about 1.3 years after every sunspot maximum and minimum, although no attempt is made to trace the relation definitely.

Dew.—Dew is quite important in astronomical work and it was found to be so heavy that a desirable means of measuring it was sought. It was measured by the following device, consisting "of a square blackened funnel measuring 60 cm. on a side and 10 cm. in depth. It is supported in a wooden box at a height of 50 cm. above the ground, and is so arranged that fresh air can reach the under side of the funnel, which is also blackened. A bottle collects the precipitated moisture. While some of this is retained on the funnel, experiment shows that this is in a large part compensated by some which is precipitated on the under side of it." The maximum dewfall recorded was one standard gallon per hundred square feet of surface.

Clearness.—The clearness of the sky and the quality of the "seeing" are, of course, of paramount importance to the astronomer. Observations were made on sunshine and starlight as well as upon the clearness of the atmosphere, and it was found that the number of clear days and nights is unusually large. Also the sky seemed much clearer than in temperate zones. "The sky appears darker, possibly owing to the complete absence of any more or less permanent auroral illumination. The most noticeable effects are in the whiteness of the Moon as distinguished from its yellow color in the north, the brilliancy of the Milky Way, the distinctness of the Zodiacal Band at midnight and of the Gegenschein, which sometimes appears as early as 9 o'clock, and the brilliancy of comets' tails." In general, it is believed that good "seeing" does not associate itself with dry air, but the very contrary, for the best "seeing" at Mandeville seemed to come on very wet nights. This tends to disprove the contention that observatories should be built in deserts. The only advantage of such a location over that in Jamaica is that there might be a greater percentage of clear nights, although that is not necessarily true.—*C. L. M.*

THE RELATION BETWEEN WIND AND THE DISTRIBUTION OF PRESSURE.[1]

By H. JEFFREYS.

[Abstract reprinted from Nature (London), July 17, 1919, p. 398.]

A classification of some 600 wind observations over the North Sea, according to their velocities and directions, showed that the most striking feature of the resulting values was their asymmetrical frequency distribution. From the fact that this was noticeable in nearly every class, it was inferred that it could be produced only by variation in turbulence or systematic contortion of the isobars, on a scale too small to be recorded on the weather map. The latter cause, however, and also such variations in turbulence as keep the coefficient of eddy viscosity the same at all heights, would lead to strong correlations between S/G and α, which are not observed. Hence it is concluded that the principal cause of variation in the relation of the surface wind to the gradient is variation in the vertical distribution of turbulence; and it is shown that such variation could give the effects actually observed.

MOTION OF THE AIR IN LOWEST LAYERS OF THE ATMOSPHERE.[2]

By G. HELLMANN.

[Abstract reprinted from Science Abstracts, July, 1919, p. 311.]

The ground wind is investigated by measurements of wind velocity at five different heights between 5 and 200 cm. above unobstructed ground near Berlin, and it is found that in this lowest layer the mean wind velocities are proportional to the fourth roots of the corresponding heights.

The previous work of the author for heights varying from 200 cm. (2 m.) to 258 m. above the ground gave rise to a similar result, in which, however, the velocities were proportional to the fifth roots of the corresponding heights.—R. C.[3]

LOCAL WIND VARIATIONS.

[Reprinted from Meteorological Office Circular, Mar. 26, 1918, pp. 2-3.]

There is a natural tendency to assume that a single anemometer gives a fair representation of the wind over a large area. A study of the records from the two anemometric stations at Southport shows that the assumption is by no means always justified. At Hesketh Park, the climatological station to which all Southport observations, except those of wind, refer, the anemometer vane is 50 feet above ground, 20 feet above the tallest trees in the park, and 30 feet above those nearest it. The records of wind strength, given by an anemobiagraph, and of direction, given by a Baxendell anemoscope, show considerable gustiness under all conditions. At the Marshside wind station, about a mile

[1] Royal Society, London, June 26, 1919.
[2] Preuss. Akad. Wiss. Berlin, Ber. 22. pp. 404–416, 1919.
[3] Cf. Prof. notes No. 6, p. 572, above.

NNE. from Hesketh Park, there is a free exposure. The vane is 62 feet above the ground, which is flat and open. There is no tree or other obstruction within ¼ mile (except some very low buildings to the SE.); while from WSW. through N. to E. is absolutely open.

The records for the instruments at this station, two Dines anemometers and a Baxendell anemoscope with twin recording cylinders, show far less gustiness than those from Hesketh Park.

The differences between the directions of the wind at the two stations are sometimes very striking. They mostly occur with fairly light winds from easterly points. There was a striking example on the night of October 1 and 2, 1917. The speed of the wind at Marshside at 23h. 30m. was 3.5 m/s and the veer from N., 124°. Up to midnight, the wind freshened and reached 5.4 m/s, then it fell off again to 2.7 m/s at 0h. 35m. During the whole of this time it was veering slowly, the direction being given by 138° at midnight and 146° at 0h. 35m.

On the other hand, at Hesketh Park, during the same period, the wind was too light for measurable speed to be given by the anemobiagraph. The direction from 23h. 30m. to midnight was about 150° from N., i. e., not far different from that at Marshside, but at midnight there was a sudden shift to 70°. Agreement was not restored for half an hour.

It will be seen that the wind at Hesketh Park during this half hour had no apparent relation to the general flow of air, such as would be shown on a weather map. It may be noted that the temperature of the air at 16h. at Hesketh Park had been 294A. At 23h. 30m. it was 284 A. so that there was probably a well-marked inversion in the upper air. As the wind at Marshside strengthened, there was a fall of the Hesketh Park temperature to 283 A. at midnight, and this was followed by a corresponding rise as the wind dropped. The direction differences are, however, by no means always associated with temperature peculiarities, and often occur with somewhat higher wind speeds than in the foregoing instance, and last longer

ON THE VELOCITY OF THE WIND IN THE STRATOSPHERE.

By J. ROUCH.

[Abstract of note in Comptes Rendus, Paris, 1919, vol. 168, pp. 1281–1283.]

In view of the generally accepted statement to the effect that winds of the stratosphere are light, the following note may be of interest. The mean wind velocity during 78 pilot-balloon ascensions which reached 10 km. altitude from coastal stations in France is as follows, for each kilometer from 0 to 10: 3.3, 5.1, 5.1, 5.0, 6.0, 6.4, 7.3, 7.9, 8.5, 9.5, 11.8. Thirty-six of these reached or exceeded 11 km. and 7 went above 15 km. If we may assume that the stratosphere was from 11 km. up, the winds in the stratosphere were stronger than those at 10 km. two times out of three. This is the case with clear weather and moderate winds below. What the conditions are when the sky is cloudy, or when the winds of the troposphere carry the balloon out of sight before it can reach the stratosphere, is unknown.—*C.F.B.*

THE DRIFT OF METEOR TRAILS.

[Abstracted from Nature, London, May 23, 1918, p. 232.]

Observations made upon the enduring trails of meteors have given some clue as to the speeds of the upper winds as well as the directions. The data as a whole are not of sufficiently accurate a character to enable definite conclusions to be drawn; nevertheless, there can be little doubt as to the general correctness of the results. The streaks of the Perseids and Leonids, which are usually seen at an altitude of 55 or 60 miles, have yielded an average movement eastward of 121 miles per hour. The individual speeds varied from nil to 360 miles per hour. Certain streaks gave evidence of a series of differing currents underlying each other, the upper sections drifting in different directions from the lower.

NOTE.—In reference to the above article in Nature, Dr. C. J. P. Cave has replied that the trails of meteors remain luminous too long to be due to heating of the air by the passage of the body. He suggests that the trail is a result of the ionization of the air by the passage of the meteor and the subsequent flow of electricity through this ionized air. He questions the reasonableness of such rapid movements in the stratosphere.—*C. L. M.*

THE PREVAILING WINDS OF THE UNITED STATES.

By ROBERT DEC. WARD.

[Abstracted from Annals of the Association of American Geographers, vol. 6, 1916, pp. 99–119.]

One of the chief factors to be considered in discussing economic climatology is the wind. As a vehicle for the transportation of moisture and temperature, it wipes out the climatic boundaries, determines rainfall and the distribution of life. Nor is the speed less important than the direction, for upon it depend both physical comfort and many of the practical activities of life. As a source of power the winds are coming more and more to be appreciated in their full significance.

The greater part of our country lies in the belt of the prevailing westerlies, although the southern States share also in the trade winds. These winds find their great initial cause in the differences of temperature and pressure between the Equator and the Poles; but they are modified greatly by local effects introduced by the North American continent, such as seasonal changes of temperature and pressure, mountains and lowlands, and the Great Lakes. The general configuration of the country, the trend of mountains and valleys, locations to windward or leeward of mountains or lakes, the hour of day or night, land and sea breezes, all these have a part in controlling the direction and velocity of the wind at a station. Indeed, so strongly marked are some of these local effects that it is difficult to believe that the prevailing winds are westerly.

It is desirable, however, in studying the broad climatic effects, to eliminate as far as possible these local influences With this in view, the winds of January and July are discussed. (See figs. 1 and 2.) "From midwinter to midsummer, taking place gradually, as winter merges into spring and spring later merges into summer, there is a great swing of the winds over the eastern United States, from the pervailing northerly and northwesterly to a prevailing southwesterly or southerly direction in July." The warmest winds of the summer are those along the Atlantic seaboard. Sunstroke weather, cholera infantum epidemics, and suffering in the crowded cities are the result; sea bathing, electric fans, thin clothing, and cooling beverages are also closely applied to these warm winds. They are of economic importance in their relation to the spread of the brown-tail moth north and east from Massachusetts, and of the cotton boll weevil north from Texas.

While we can not claim the existence of monsoons, there is, nevertheless, a marked monsoonal tendency over a large section of the country. The general swing of the winds from northerly in winter to southerly in summer is very well marked in Texas. The cyclonic interruptions and weaker pressure controls, however, prevent any such strong or definitely marked effect as exists in India.

It is difficult to obtain accurate charts of wind velocities because the lack of uniformity of the data. In general, the highest average wind velocities are to be found along the Atlantic coast and over the Great Lakes. Hence the well-known stormy conditions off Cape Hatteras and the popular appelation of Chicago as the windy city—a term equally applicable to many Lake cities.

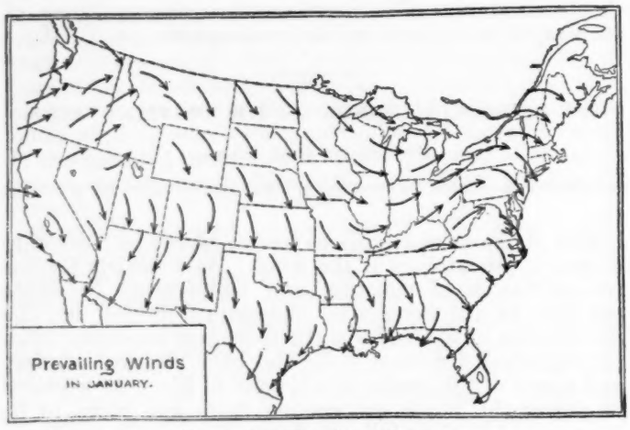


FIG. 1.—Prevailing winds in January.

FIG. 2.—Prevailing winds in July.

Among the mountains, forests, and sheltered valleys, wind velocities are less. The Great Plains are almost ocean-like in their level monotony, and, as a result, higher winds are to be found there.

This is a fact of great economic importance for these winds are well adapted to driving windmills. Irrigation, stock raising, and domestic water supply in the Middle West are largely dependent upon underground currents of water. This necessitates pumping, and the wind conditions—relatively high velocity and steady—are so well adapted to this work as to make the raising of water economical and reliable. The Plateau region and the Pacific coast are irregular and variable in their wind velocities, so that it is difficult to estimate their economic possibilities, although, without doubt, there are many places where wind power could be used to great advantage.

Of course, the highest wind speeds are those of the tornado, which invariably destroy any recording apparatus, but which, it is estimated, attain as high as 300 miles per hour. Second to tornadoes in destructiveness come the sudden squalls which accompany thundershowers. West Indian hurricanes are responsible for the maximum wind velocities recorded on the Atlantic and Gulf coasts, while severe winter storms bring highest winds in the northern coast and Great Lakes regions. Maximum wind velocities are of importance because of their relation to shipping, uprooting of timber, and damaging of crops.

March is a proverbially windy month. This is true because it is a transition month, i. e., a time when the weather controls are passing from the winter to the summer, and there is a combined effect of the active winter controls and the rapidly increasing solar control. There is less seasonal variation over the Great Plains than in other parts of the country. This fact makes the winds in those regions conspicuous and important as a reliable source of power.—*C. L. M.*

THE WINDS OF BOSTON AND VICINITY.

By ALEXANDER MCADIE.

[Abstract from Annals of the Astronomical Observatory of Harvard College, vol. 73, part 3, 1916, pp. 211–231, and vol. 83, part 1, 1917, pp. 28–46. Plates]

The climate of a locality depends primarily upon the circulation of the lower atmosphere. In spite of the considerable impression which the chilly easterly winds make on people, they are the least frequent and west winds the most frequent. Owing to the difference in the exposure of anemometers in Boston and at the Blue Hill Observatory, the average wind velocity at Blue Hill is about 60 per cent greater than in the city. The average mid-winter wind velocity is 8.2 meters per second, and the average midsummer velocity is 5.5 meters per second. The diurnal maximum velocity occurs in the afternoon and the minimum in the forenoon, the latter amounting to about 80 per cent of the former.

The highest wind velocity ever recorded at Blue Hill was 32 meters per second from the southeast on January 2, 1893, and the same velocity on February 10, 1909, this time from the south. The extreme velocity for a single minute has frequently exceeded 35 meters per second. The winds of summer are weaker than those of winter regardless of their direction. The weakest winter winds are from the east, with a mean velocity of less than 7 meters per second, and the weakest summer winds are the east-southeast and east, with velocities averaging 4 meters per second.

In general, months of excessive rainfall are months in which the northeast wind has a maximum duration. The average rainfall along the New England coast is about 1000 mm., while inland about 100 miles this value shrinks to about 800 mm. Consequently, the Atlantic seaboard is generally said to have a moist climate. This is, of course, relatively true; nevertheless, the climate is essentially dry, because the prevailing winds blow from the land. "If it were possible to reverse the surface circulation and substitute for the west wind, the east wind, the total rainfall would be 50 per cent greater and the number of rainy days would exceed 250 instead of the present number 106, or approximately 9 per month."

The excessive rainfall of the north Pacific slope is a good illustration of the effect of the prevailing winds blowing off of a water surface. Naturally, then, the excessively dry periods at Boston are characterized by the west wind.

The sea breeze must be considered one of the minor factors in the climate of New England. This is a very shallow wind and frequently does not exceed 250 meters in depth as shown by pilot-balloon ascensions. It is easily distinguished from the "sea turn" by its more rapid decrease in temperature and also by the fact that it is more gusty. The "sea turn" is of cyclonic origin and is of much greater depth. The temperature drop which occurs with a thunderstorm is well known, but it is not nearly so marked a drop as occurs with the incoming of the sea breeze.

From observations with kites, sounding balloons, pilot balloons, and clouds it appears that about 90 per cent of the time the wind speed increases up to the base of the stratosphere. Occasionally the speed does decrease with altitude, but this generally occurs when there is a strong surface wind, from the north and northwest, after the passage of a storm out the St. Lawrence Valley.

The discussion of the winds at Boston is concluded with a discussion of the theories of circulation and of cyclonic origin and structure.—*C. L. M.*

PAMPHLET ON MARINE WORK.

The Weather Bureau has recently published a pamphlet (W. B. No. 678, "The Marine Meteorological Service of the United States") descriptive of its marine work, the object being to direct attention to this particular branch of the bureau's activities and the existing need for more weather and water-temperature observations from ocean-going ships. Chapters are devoted to the following subjects: History of American Marine Meteorology, the Present Commercial Value of Marine Meteorological Work, Some Specific Needs for More Marine Observations, Marine Observations in Daily and Seasonal Weather Forecasts, Observations and Instruments.

During the war comparatively few ships' observations were collected and the marine work suffered accordingly. The termination of hostilities, however, permitted of steps being taken to build up the observational part of the work and the revival of the American merchant marine has directed attention to, and quickened interest in, the whole subject of ocean meteorology.

Copies of the pamphlet will be sent to any address on request.

REVIVAL IN MARINE WORK.

A compilation which has just been made shows that since March last, some 357 ships have indicated a willingness to furnish reports to the Bureau. Some of these ships rendered reports prior to the war. Below is given by nationalities, the present number of observing ships and the recent additions thereto.

Nationality.	Present number of reporting vessels.	Number secured since March, 1919.
American	588	194
British	526	87
Japanese	133	17
Dutch	127	12
French	63	10
Italian	55	16
Danish	43	.....
Norwegian	40	5
Spanish	25	2
Belgian	19	6
Swedish	11	2
Russian	8	.....
Honduran	4	.....
Chinese	4	3
Brazilian	2	1
Portuguese	2	1
Chilian	1	1
Argentinian	1	.....
Interallied	1	1
Total	1,653	357

F. G. Tingley.

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RECENT ADDITIONS TO THE WEATHER BUREAU LIBRARY.

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The investigation of the air. A lecture delivered in the Aula Magna of the Malta university on the 19th of May, 1919. Malta, 1919. 29 p. 25 cm.

Bigourdan, G[uillaume]

La température moyenne des diverses parties de la France. charts. tables. 15½ cm. (Excerpted from Annuaire pour l'an 1912, publié par le Bureau des longitudes, Paris. p. A1–A47.)

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Commerce and the weather. Buenos Aires. 1918. 14 p. 18 cm.

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The sound-waves and other air-waves of the East London explosion of January 19, 1917. Edinburgh. 1818. cover-title. 3 maps. 25½ cm. (Reprint from the Proceedings of the Royal Society of Edinburgh. Session 1917–1918. Vol. 38, part 2, no. 12, p. [115]–129.)

Dorno, C[arl Wilhelm Max]

Beobachtungen der Dämmerung und von Ringerscheinungen um die Sonne 1911 bis 1917. Berlin. 1917. 2 p. l., 94 p. tables (part. fold.) 34 cm. (Veröffentlichungen des K. Preussischen meteorologischen Instituts. Nr. 295. Abhandlungen Bd. 5. Nr. 5.)

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Himmelshelligkeit, Himmelspolarisation und Sonnenintensität in Davos 1911 bis 1918. Braunschweig. 1919. cover-title. charts. tables. 29½ cm. (Sonderabdruck aus "Meteorologische Zeitschrift," 36 Band, Heft 5/6 und 7/8, p. [109]–124; [181]–192.)

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C. FITZHUGH TALMAN, Professor in Charge of Library.

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SPECIAL OBSERVATIONS.

SOLAR AND SKY RADIATION MEASUREMENTS DURING AUGUST, 1919.

By HERBERT H. KIMBALL, Professor of Meteorology, in Charge.

[Dated: Solar Radiation Investigations Section, Washington, Sept. 29, 1919.]

For a description of instrumental exposures, and an account of the methods of obtaining and reducing the measurements, the reader is referred to the REVIEW for January, 1919, **47**:4.

The monthly means and departures from normal in Table 1 show that radiation measurements averaged close to August normal values at Washington and above normal at Madison and Lincoln. But few measurements were obtained at Santa Fe on account of clouds the first of the month and smoke from forest fires during the last decade of the month. At Madison a noon reading of 1.41 cal. per square centimeter per minute measured on the 31st is the highest intensity ever measured at that station in August.

Table 3 shows an excess of 12 per cent for Madison and 5 per cent for Lincoln in the total radiation for the month as compared with the normal amounts for August. The total for Washington is close to normal.

The skylight polarization measurements made at Washington on seven days give a mean of 50 per cent, with a maximum of 65 per cent on the 2d. At Madison, measurements made on 18 days give a mean of 61 per cent, with a maximum of 71 per cent on the 25th. These are average values for August.

TABLE 1.—*Solar radiation intensities during August, 1919.*

[Gram-calories per minute per square centimeter of normal surface.]

Washington, D. C.

Date.	Sun's zenith distance. 0.0°	48.3°	60.0°	66.5°	70.7°	73.6°	75.7°	77.4°	78.7°	79.8°
	Air mass. 1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5
A. M.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
Aug. 2	1.36	1.28	1.20	1.12	1.04	0.98	0.93	0.87	0.81	.....
11	1.14	0.89	0.71	0.62	0.53	0.41	.....	.....	.....	.....
14	.....	0.95	0.75	0.64	.....	.....	.....	.....	.....	.....
15	.....	0.93	0.75	0.50	.....	.....	.....	.....	.....	.....
16	.....	.....	0.82	0.70	0.60	0.55	0.51	.....	.....	.....
19	.....	1.06	0.93	0.82	0.72	0.64	0.58	0.52	0.47	.....
20	1.20	1.09	0.98	0.89	0.80	0.72	0.65	0.56	.....	.....
22	1.24	1.05	.....	.....	.....	.....	.....	.....	.....	.....
23	1.25	0.90	0.74	0.64	0.57	.....	.....	.....	.....	.....
26	.....	1.21	1.04	0.91	0.80	0.70	.....	.....	.....	.....
27	.....	1.13	.....	.....	.....	.....	.....	.....	.....	.....
Monthly means	**1.24**	**1.05**	**0.88**	**0.76**	**0.72**	**0.67**	**0.67**	**0.65**	**(0.64)**	.....
Departure from 11-year normal	±0.00	−0.01	−0.02	−0.05	−0.02	+0.02	−0.01	+0.06	+0.06	.....
P. M.										
Aug. 9	.....	1.29	1.20	1.12	1.04	.....	.....	.....	.....	.....
14	.....	.....	0.72	0.62	.....	.....	.....	.....	.....	.....
22	.....	.....	1.05	.....	.....	.....	.....	.....	.....	.....
26	.....	0.88	.....	.....	.....	.....	.....	.....	.....	.....
Monthly means	.....	**(1.08)**	**0.99**	**(0.87)**	**(1.04)**	.....	.....	.....	.....	.....
Departure from 11-year normal	.....	**−0.01**	**+0.02**	**+0.01**	**+0.25**	.....	.....	.....	.....	.....

Madison, Wis.

A. M.										
Aug. 1	1.36	1.22	1.06	0.98	0.94	0.88	0.84	0.80	.....	.....
2	1.33	1.24	1.16	1.08	1.00	0.94	0.89	0.85	.....	.....
7	.....	1.28	1.19	1.10	.....	.....	.....	.....	.....	.....
8	1.42	1.32	1.23	1.13	1.06	0.99	0.94	0.91	.....	.....
9	1.40	1.26	1.14	1.04	0.98	0.92	0.87	0.82	0.78	.....
13	1.41	.....	.....	.....	.....	.....	.....	.....	.....	.....
14	.....	1.09	0.96	.....	.....	.....	.....	.....	.....	.....

TABLE 1.—*Solar radiation intensities during August, 1919*—Contd.

Madison, Wis.—Continued.

Date.	Sun's zenith distance. 0.0°	48.3°	60.0°	66.5°	70.7°	73.6°	75.7°	77.4°	78.7°	79.8°
	Air mass. 1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5
A. M.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
Aug. 16	1.37	1.26	1.17	.....	.....	0.92	.....	0.79	.....	.....
18	.....	1.06	0.83	0.71	0.61	0.59	.....	.....	.....	.....
19	1.38	1.27	1.17	1.08	1.00	0.95	0.90	0.87	.....	.....
21	1.42	1.28	1.17	1.07	1.00	0.90	0.87	0.82	.....	0.71
22	1.41	1.29	1.17	1.07	1.00	0.93	0.86	0.78	.....	.....
23	.....	0.81	.....	.....	.....	.....	.....	.....	.....	.....
25	.....	1.34	1.26	1.18	.....	.....	.....	.....	.....	.....
26	.....	1.25	.....	1.03	0.95	.....	.....	.....	.....	.....
27	.....	1.31	1.21	1.11	1.04	0.98	0.92	0.88	.....	.....
28	.....	1.28	1.19	.....	.....	.....	.....	.....	.....	.....
30	.....	1.25	1.17	1.01	0.91	0.83	0.75	0.67	.....	.....
31	1.46	1.35	1.25	.....	.....	0.93	0.84	0.77	.....	.....
Monthly means	**1.40**	**1.23**	**1.15**	**1.05**	**0.95**	**0.90**	**0.87**	**0.81**	**(0.78)**	**(0.71)**
Departure from 10-year normal	+0.08	+0.03	+0.05	+0.03	+0.03	+0.02	+0.04	+0.01	+0.05	.....
P. M.										
Aug. 1	.....	1.25	1.14	.....	.....	.....	.....	.....	.....	.....
7	.....	1.25	.....	.....	.....	.....	.....	.....	.....	.....
13	.....	1.25	1.10	1.02	0.93	0.84	.....	.....	.....	.....
19	.....	1.22	1.06	.....	.....	.....	.....	.....	.....	.....
21	.....	1.32	1.20	1.10	1.02	0.94	.....	.....	.....	.....
22	.....	0.95	.....	.....	.....	.....	.....	.....	.....	.....
25	.....	1.33	1.23	1.14	.....	.....	.....	.....	.....	.....
26	.....	1.12	.....	.....	.....	.....	.....	.....	.....	.....
27	.....	1.30	1.20	1.09	0.97	.....	.....	.....	.....	.....
28	.....	1.29	1.18	.....	.....	.....	.....	.....	.....	.....
Monthly means	.....	**1.23**	**1.16**	**1.09**	**0.97**	**(0.89)**	.....	.....	.....	.....
Departure from 10-year normal	.....	+0.07	+0.11	+0.11	+0.10	+0.08	.....	.....	.....	.....

Lincoln, Nebr.

A. M.										
Aug. 13	.....	1.34	1.21	1.11	0.99	0.93	0.88	0.84	.....	.....
14	.....	.....	.....	0.97	0.90	0.83	.....	.....	.....	.....
16	(1.36[1])	1.21	1.11	0.99	0.91	0.84	.....	.....	.....	.....
18	.....	1.28	1.16	1.10	1.03	0.96	.....	.....	.....	.....
Monthly means	.....	**1.28**	**1.16**	**1.04**	**0.96**	**0.89**	**(0.88)**	**(0.84)**	.....	.....
Departure from 5-year normal	.....	+0.08	+0.08	+0.04	+0.06	+0.03	+0.07	+0.09	.....	.....
P. M.										
Aug. 3	(1.40[1])	1.22	1.09	0.99	0.91	0.83	0.75	0.69	.....	.....
11	.....	.....	.....	0.90	.....	.....	.....	.....	.....	.....
12	.....	.....	.....	0.84	.....	.....	.....	.....	.....	.....
13	.....	1.24	1.14	1.08	0.97	0.88	0.81	0.77	0.68	0.61
14	.....	1.14	0.99	0.84	.....	.....	.....	.....	.....	0.43
16	(1.39[1])	1.26	1.16	1.08	1.00	0.95	0.89	0.84	.....	.....
18	(1.44[1])	1.31	1.20	1.11	1.04	0.97	0.91	0.86	0.82	0.78
Monthly means	.....	**1.23**	**1.12**	**0.98**	**0.98**	**0.91**	**0.84**	**0.79**	**(0.75)**	**0.61**
Departure from 5-year normal	.....	+0.02	+0.01	−0.03	+0.05	+0.05	+0.06	+0.04	+0.03	−0.07

[1] Extrapolated, and reduced to mean solar distance.

Santa Fe, N. Mex.

A. M.										
Aug. 4	.....	.....	.....	.....	1.16	1.06	.....	.....	.....	.....
13	.....	.....	.....	.....	1.18	1.04	0.92	.....	.....	.....
18	1.43	.....	.....	.....	.....	.....	.....	.....	.....	.....
26	1.32	.....	.....	.....	.....	.....	.....	.....	.....	.....
Monthly means	(1.38)	.....	.....	.....	(1.17)	(1.05)	(0.92)	.....	.....	.....
Departure from 7-year normal	−0.03	.....	.....	.....	+0.09	+0.04	−0.02	.....	.....	.....
P. M.										
Aug. 29	.....	1.28	1.17	1.08	.....	.....	.....	.....	.....	.....
Monthly means	.....	(1.28)	(1.17)	(1.08)	.....	.....	.....	.....	.....	.....
Departure from 2-year normal	.....	−0.10	−0.07	−0.08	.....	.....	.....	.....	.....	.....

TABLE 2.—*Vapor pressures at pyrheliometric stations on days when solar radiation intensities were measured.*

Washington, D. C.			Madison, Wis.			Lincoln, Nebr.			Santa Fe, N. Mex.		
Date.	8 a.m.	8 p.m.	Date.	8 a.m.	8 p.m.	Date.	8 a.m.	8 p.m.	Date.	8 a.m.	8 p.m.
1919.	*mm.*	*mm.*	1919.	*mm.*	*mm.*	1919.	*mm.*	*mm.*	1919.	*mm.*	*mm.*
Aug. 2	9.14	11.38	Aug.1	9.83	8.48	Aug.3	17.37	13.13	Aug.4	8.81	8.18
9	8.48	11.81	2	11.38	9.14	11	15.11	16.20	13	7.29	8.81
11	13.61	14.60	7	14.10	13.13	12	15.11	20.57	18	9.14	8.48
14	10.59	16.79	8	9.83	9.83	13	12.24	14.10	26	7.04	6.50
15	16.20	19.23	9	10.21	7.04	14	10.59	18.59	29	8.18	7.87
16	15.11	17.37	13	15.11	14.10	16	9.14	11.38	.....	.....	.....
19	15.65	17.96	14	14.60	14.60	18	9.83	9.83	.....	.....	.....
20	14.60	17.96	16	10.97	12.68	.....	.....	.....	.....	.....	.....
22	15.11	13.61	18	13.13	12.24	.....	.....	.....	.....	.....	.....
23	14.10	20.57	19	11.38	11.81	.....	.....	.....	.....	.....	.....
26	9.52	10.59	21	10.97	8.48	.....	.....	.....	.....	.....	.....
27	9.14	11.81	22	12.24	16.20	.....	.....	.....	.....	.....	.....
.....	.....	.....	23	16.20	16.79	.....	.....	.....	.....	.....	.....
.....	.....	.....	25	9.47	8.18	.....	.....	.....	.....	.....	.....
.....	.....	.....	26	8.48	8.81	.....	.....	.....	.....	.....	.....
.....	.....	.....	27	7.87	7.57	.....	.....	.....	.....	.....	.....
.....	.....	.....	28	7.04	7.87	.....	.....	.....	.....	.....	.....
.....	.....	.....	30	9.14	8.81	.....	.....	.....	.....	.....	.....
.....	.....	.....	31	8.18	9.14	.....	.....	.....	.....	.....	.....

TABLE 3.—*Daily totals and departures of solar and sky radiation during August, 1919.*

[Gram-calories per square centimeter of horizontal surface.]

Day of month.	Daily totals.			Departure from normal.			Excess or deficiency since first of month.		
	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.
	cal.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
1	405	679	170	− 73	202	−379	− 73	202	−379
2	616	611	488	139	137	− 59	66	339	−438
3	569	253	700	92	−218	155	158	121	−283
4	333	357	523	−143	−111	− 29	15	10	−303
5	225	351	609	−251	−114	68	−236	−104	−235
6	223	270	593	−251	−193	56	−487	−297	−179
7	462	620	684	− 9	159	152	−496	−138	− 27
8	500	639	584	31	179	56	−465	41	29
9	630	578	611	164	120	87	−301	161	116
10	579	574	518	115	117	− 2	−186	278	114
11	550	216	604	89	−239	89	− 97	39	203
12	458	518	345	0	64	−166	− 97	103	37
13	100	470	669	−355	18	163	−452	121	200
14	442	563	643	− 10	112	141	−462	233	341
15	486	475	480	37	26	− 18	−425	259	323
16	500	575	656	54	128	161	−371	387	484
17	378	384	686	− 64	− 60	195	−435	327	679
18	425	556	661	− 14	115	173	−449	442	852
19	473	540	230	37	102	−255	−412	544	597
20	550	271	567	118	−165	85	−294	379	682
Decade departure							−108	101	568
21	288	597	558	−141	164	80	−435	543	762
22	522	540	545	96	110	70	−339	653	832
23	498	512	539	76	85	67	−263	738	899
24	491	522	508	72	98	40	−191	836	939
25	328	592	495	− 88	171	− 60	−279	1,007	879
26	509	549	168	95	131	−295	−184	1,138	584
27	376	585	251	− 36	170	−209	−220	1,308	375
28	503	564	530	93	153	72	−127	1,461	447
29	478	332	463	70	− 76	7	− 57	1,385	454
30	158	465	612	−248	60	158	−305	1,445	612
31	433	539	620	28	138	168	−277	1,583	780
Decade departure							+ 17	+1,204	+ 98
Excess or deficiency since first of year. } gr.-cal.							−4,697	−3,366	−1,938
Excess or deficiency since first of year. } per cent							−5.0	−3.6	−1.8

MEASUREMENTS OF THE SOLAR CONSTANT OF RADIATION AT CALAMA, CHILE.

By C. G. ABBOT, Director, Astrophysical Observatory.

[Dated: Smithsonian Institution, Washington, September, 1919.]

In continuation of the publications begun in February, 1919, I give herewith the values of the solar constant of radiation obtained at Calama, Chile, for the months of June and July, 1919.

I was present in Calama at the time that many of these observations were made, and in cooperation with the observers there worked out a new method of observing which has been employed for some of the days of observation included in the following tables, and which shall be briefly described as follows:

My colleagues, Mr. Fowle and Mr. Aldrich, as well as those in Calama, and myself have felt very keenly the desirability of devising some method of determining the solar constant of radiation which would be independent of changes in the transparency of the atmosphere during the period of observation. I had hoped that this might be done in some simple form by the aid of the pyranometer, that instrument which we devised several years ago for the purpose of measuring the brightness of the sky. It is well known that when the sky becomes more hazy the direct beam of the sun is reduced in intensity, but the scattered light of the sky is at the same time increased. Accordingly, it would seem that a pyranometer measurement of the brightness of a limited area of the sky near the sun would furnish an index of the state of the transparency of the atmosphere at the moment of observation, and this, combined with the usual observations of the solar intensity at the earth's surface by the pyrheliometer, and combined further with the determination of the quantity of the aqueous vapor between the observer and the sun (which is indicated by the state of the great infra-red absorption bands, ρ and ϕ) might give the means of estimating the solar radiation outside the atmosphere from observations made at a single instant of time.

When I reached Calama, after having observed the total eclipse of the sun at La Paz and having held a conference with Messrs. Wiggin and Clayton of the Argentine Weather Service at La Quiaca, Argentina, I found that Messrs. Moore and Abbot had prepared data giving the pyrheliometry, the transparency of the atmosphere for nearly 40 wave lengths, the function ρ/ρ_{sc}, and pyranometer values representing the intensity of the radiation of the sky in a zone 15° wide surrounding the sun. All these values were tabulated with solar constant values for 60 days of observation. They were taken for each day at the periods when the air masses were 2 and 3, respectively. I spent almost a week in working over these data, trying to find some method of combining them along the lines which I have suggested above, but without success. Mr. Moore, however, had once or twice suggested to me that if we knew the coefficient of atmospheric transmission for all of the individual wave lengths on a given day, and had observed with the spectrobolometer and pyrheliometer at air mass 2 or at air mass 3, we could determine the solar constant from these data

at once. I had always replied to him that there are no means of determining the transparency of the atmosphere at these wave lengths without the process of taking successive bolographs during several hours of time, which brought in the very errors which we were endeavoring to avoid. All simple means having failed to give a satisfactory method, Mr. Moore's suggestion recurred to me, and I actually found that it is possible, by noting the value of the function ρ/ρ_{sc}, and the intensity of the sky light in the neighborhood of the sun, to determine at once the transmission coefficients for all wave lengths. This we do by means of plots in which the data for the 60 days mentioned are employed. These data were used in the following manner:

Taking the value obtained at air mass 2 by the pyranometer for the limited area of sky around the sun, dividing it by the value of ρ/ρ_{sc} at the corresponding time, we obtain a function which we may call "F." Plotting values of "F" as abscissæ against values of the transmission coefficients for each measured wave length as ordinates, we obtain about 40 plots. These for the infra-red region of the spectrum are nearly straight lines, but they become more and more convex toward the axes of coordinates for the rays of shorter wave lengths. In the 60 days which were available for the investigations, the function "F"ranged through values running from 100 to more than 1,000 of a certain scale, while the function "a," that is the transmission coefficient, ranged only through a very few per cent. For a large portion of the spectrum, including the infra-red region, the range of "a" was hardly more than 1 or 2 per cent. Accordingly great error is allowable in the function "F" without greatly affecting the accuracy of the inference as to the value of the function "a." In short, by means of the function "F" we are able to determine the function "a" for all wave lengths, with highly satisfactory accuracy, from observations at a single point of time. Thus changes of the atmospheric transparency during the period of observation are avoided.

We shall hereafter employ this new method in combination with the old, not only for air mass 2 but for air mass 3, and shall check one against the other frequently for a considerable period of time until we are abundantly satisfied of the accuracy of the new method of observation. In general we regard observation at air mass 3 as of half the weight of observation at air mass 2. Hitherto, the new method has enabled us to save a number of days of observation which, owing to the obvious changes in transparency of the atmosphere, due to formation or disappearance of clouds, would otherwise have been lost, and some of the observations published herewith for June and July are of this character.

As it is impossible to use our former criterion, based upon the several hours of observation, to determine the excellence of the day, we have altered the statement of the grade by the introduction of two new symbols, "S" meaning satisfactory, and "U" meaning unsatisfactory, for those days in which the solar constant has been determined by the new method. So far as we have as yet been able to compare the results by the old and the new methods, they are on the average closely identical. For instance, on July 1 three values of the solar constant were computed: 1, by the old process; 2, from observations at air mass 2; 3, from observations at air mass 3. The results obtained were as follows: 1.948, 1.940, 1.955, all agreeing within less than 1 per cent, and the mean of the results by the new process agreeing identically with the result by the old.

The new process requires but two or three hours of work where the old required about 15, so that if it continues to appear satisfactory as now a very great gain in labor will result from it. Not only is this so, but a still greater gain, we think, will come in accuracy for we have now eliminated the fruitful source of error depending on the variability of the atmospheric transparency during the observations.

In the future we expect, if all goes well, to determine about two-thirds of the solar constant values exclusively by the new process and the other third at intervals by the old, in addition, to assure ourselves that nothing is going astray. An advantage of the new method is that on days when the early morning is unsuitable for observation but later it clears away so as to be satisfactory for 15° around the sun, a good solar constant value can be obtained by the new method where nothing at all of value could be obtained by the old. It is probable that at Calama the increase in the number of days fit for observation owing to this improvement will be four or five days a month, or possibly more. Also some of the days when we would have had great distrust of the results, owing to probable changes of transparency, will now be made of almost or quite equal excellence to the others.

Apart from this (as it seems to me), very valuable result of my visit to Calama, I was much impressed with the excellent character of the outfit there and with the great zeal and thoroughness with which Messrs. Moore and Abbot are carrying on their observations.

I now give results for June and July. An explanation of the symbols and arrangements of the tables heretofore employed will be found by the reader in the MONTHLY WEATHER REVIEW for February, 1919. Beginning with the month of June, the following slight changes will be made in the publication of the results:

First, a new column, headed "Method," will be inserted after the column headed "Solar Constant." In this will be found the symbols E_0, M_2, M_3, W.M., and occasionally, where the new method has been employed at air masses—differing from 2 and 3, such a symbol as $M_{2.5}$ will be found. The significance of these symbols is as follows: E_0 indicates that the observation was made and reduced by the old method heretofore employed. M_2, M_3, or M, with some other subscript, means that observations were made and reduced by the new method from air mass 2, air mass 3, or some other value which was more suitable on the day in question. The symbol W.M. means that the solar constant value preceding it was the weighted mean of all of the results for the day as determined by the best judgment of the observers at Calama. Thus, on July 21 we have given four values, respectively, 1.947 by the old method, marked "E_0;" 1.955 by the new method from air mass 3, marked "M_3"; 1.955 by the new method at air mass 2, marked "M_2"; and 1.953 marked "W.M.," which is the weighted mean according to the best judgment of the observers at Calama. The values marked "W.M." are to be preferred in the use of the data for purposes of comparison with the phenomena of the weather.

In the next column, marked "Grade," we have introduced, as above indicated, the new symbols "S" and "U," with the suffixes "plus" or "minus" to indicate the degree of satisfactoriness or unsatisfactoriness which prevailed in determining the solar constant by the new method.

The columns marked "Humidity" are to be interpreted as follows: Where the observation has been made by the old method, as indicated by the symbol E_0, the values of humidity are to be understood as the *mean* of all those

determined during the interval of the observations. Those which occur, as for example on June 25, on the days when the solar constant was not determined by the old method at all are to be taken as obtained at the time corresponding to the air mass given as a subscript under the letter M in the column headed "Method." Thus, on June 25 the values of humidity correspond to air mass 2; that is to say, to the time when the sun was at 60° zenith distance.

In other respects there is no change in the character of the tables.

Date.	Solar constant cal.	Method.	Grade.	Transmission coefficient at 0.5 micron.	Humidity.			Remarks.
					ρ/ρ_{sc}	V. P.	Rel. hum.	
						Cm.	*P. ct.*	
A.M.								
June 1	1.962	E_0	VG	0.882	0.645	0.08	11	Cloudless except distant cirri in southwest.
P.M.								
June 2	1.898	E_0	E−	.877	.558	.24	18	
3	1.933	E_0	E−	.874	.707	.18	10	Cirri in west at start drifting to north.
A.M.								
June 4	1.989	E_0	E−	.866	.738	.06	7	
5	1.947	E_0	E	.867	.740	.07	10	
9	1.955	E_0	E−	.877	.498	.21	26	Distant cirri disappearing early.
10	2.013	E_0	VG−	.839	.531	.22	27	
14	1.972	E_0	E−	.859	.372	.44	43	Many cumuli scattered about sky.
15	1.873	E_0	VG+	.872	.432	.33	42	Many scattered cumuli passing over sun at intervals.
	1.918	M_2						
	1.903	W.M.						
16	1.927	E_0	E−	.875	.436	.31	36	Cumuli in distant northeast.
P.M.								
19	1.934	E_0	E−	.869	.543	.27	24	Scattered small cumuli in east.
A.M.								
20	1.956	E_0	VG+	.874	.700	.11	18	Cirri near sun at start.
21	2.013	E_0	E−	.856	.686	.08	10	Cirri in distan west.
22	1.959	E_0	E−	.871	.652	.08	10	
23	1.975	E_0	E−	.871	.756	.06	9	Sky cloudless. Smoke toward west.
24	1.952	E_0	E−	.876	.723	.04	5	Few cirri in southwest disappearing by 10:00.
25	1.955	M_3	S	.874	.735	.04	6	Small cirri scattered about sky.
26	1.926	M_3	S	.878	.767	.15	15	Thin cirri in northeast.
27	1.964	E_0	S	.861	.782	.10	15	Thin cirri in northeast mostly below sun.
	1.938	M_2						
	1.938	W.M.						
P.M.								
28	1.972	M_2	S	.873	.723	.12	8	Many cirri in east and rather uneven in west.
A.M.								
29	1.969	M_2	S	.864	.610	.30	31	Thin cirri and streakiness in east. Small cumuli forming over Andes.
30	1.962	M_2	S	.861	.662	.31	29	Sky cloudless but hazy and very dusty.
A.M.								
July 1	1.948	E_0	VG+	.859	.638	.14	16	
	1.925	M_3						
	1.934	M_2						
	1.935	W.M.						
A.M.								
July 2	1.918	M_2	S−	.867	.664	.13	12	
3	1.928	E_0	VG+	.860	.600	.14	17	
	1.927	M_3						
	1.917	M_2						
	1.922	W.M.						
4	1.968	M_3	S	.865	.479	.16	21	Low cumuli in east.
6	1.964	M_2	S	.869	.521	.19	20	Cirro-cumuli in east, cirri in west.
9	1.947	M_2	S	.872	.636	.32	45	Scattered cirri in north and east, and some cumuli over Andes.
10	1.951	M_2	S	.869	.635	.09	11	Some cirri in distant northeast.
11	1.945	M_3	S+	.869	.528	.10	13	Distant cirri in east and west.
	1.946	M_2						
	1.946	W.M.						
12	1.932	E_0	E−	.869	.487	.13	18	Considerable cirri in south and distant west; also below sun.
	1.969	M_3						
	1.947	M_2						
	1.949	W.M.						
13	1.929	M_3	S	.877	.564	.13	16	Scattered cirri around west, south, and east.
	1.937	M_2						
	1.934	W.M.						
14	1.953	M_3	S	.870	.556	.10	14	Scattered cirri, especially in south and west.
15	1.949	M_3	S	.850	.641	.09	11	Considerable cirri in southwest and some in north and east.
	1.954	M_2						
	1.952	W.M.						
17	1.952	E_0	G	.853	.686	.09	13	Low cirri in southwest.
	1.933	$M_{2.5}$						
	1.964	M_2						
	1.955	W.M.						
18	1.951	E_0	VG+	.873	.552	.07	8	Some low cirri in east—small patches in southwest.
	1.986	M_3						
	1.963	M_2						
	1.966	W.M.						
19	1.984	M_3	S	.866	.488	.17	15	Small cirri scattered about sky.
	1.976	M_3						
	1.979	W.M.						
20	1.955	M_3	S	.864	.538	.22	21	
	1.951	M_2						
	1.952	W.M.						
21	1.947	E_0	E	.857	.573	.17	23	
	1.955	M_3						
	1.955	M_2						
	1.953	W.M.						
22	1.983	M_3	S−	.858	.472	.21	28	
	1.952	M_2						
	1.960	W.M.						
23	1.961	M_3	S+	.873	.617	.13	17	
	1.962	$M_{2.5}$						
	1.957	M_2						
	1.959	W.M.						
24	1.928	E_0	VG+	.875	.636	.10	13	
	1.962	M_2						
	1.951	W.M.						
25	1.957	M_3	S+	.873	.729	.09	10	
	1.961	M_2						
	1.960	W.M.						
26	1.868	M_3	U	.865	.743	.06	7	
	1.935	M_2	S					
	1.918	W.M.						
27	1.891	M_3	S−	.866	.667	.08	8	
	1.929	M_2						
	1.916	W.M.						
28	1.959	E_0	E	.863	.562	.08	9	
	1.959	M_3						
	1.947	M_2						
	1.955	W.M.						
29	1.951	$M_{1.58}$	S−	.869	.588	.20	12	Scattered cirro-cumulus, especially in east.
30	1.939	M_3	S	.868	.496	.17	20	
	1.922	M_2						
	1.928	W.M.						
31	1.892	M_3	S−	.872	.591	.14	18	
	1.938	M_2						
	1.915	W.M.						

WEATHER OF THE MONTH.

WEATHER OF NORTH AMERICA AND ADJACENT OCEANS.

GENERAL CONDITIONS.

By A. J. HENRY, Meteorologist.

The ocean highs which become firmly established in the Northern Hemisphere in July begin to contract in area and the barometric level begins to sink in August as continental pressures increase somewhat. The continental low pressure of Asia increases 0.05 to 0.10 inches, and in general the annual swing in the pressure from summer to winter begins. The wind directions in August are not so clearly influenced by the pressure distribution as in the preceding month.

WEATHER OF THE NORTH PACIFIC OCEAN.

By F. G. TINGLEY.

Reports at hand indicate that no less than five distinct disturbances were experienced in Asiatic waters during the month of August. It is impossible at this writing, with the somewhat meager information available, to give accurately the tracks of these storms or to say whether all were well-developed typhoons. Complete accounts will appear later in the Monthly Bulletin of the Philippine Weather Bureau.

The first of these tropical storms made its appearance at the end of July and, on August 1, according to press reports, interrupted telegraphic communications between China, Japan, and the Philippines. It seems to have reached the Sea of Japan, in diminished form, by the 4th.

The second disturbance, which was probably of moderate intensity, caused strong southwest to west winds on the steamer route between Manila and Hongkong during the 6th to 8th.

During the period from the 12th to 15th strong winds, which apparently backed from northeast to west, were experienced in the Eastern Sea.

From the 18th to the 22d a disturbance traveled from a position east of Luzon to the westward, across the China Sea. This typhoon was followed almost immediately by another, which appeared in about the same region but which pursued a different course traveling more to the northwestward and reaching the China coast north of Amoy about the 25th. The American S. S. *Nanking* experienced very heavy weather in this storm but was not near enough to the center to record an extremely low pressure, the lowest reading reported being 29.30 on the 25th.

INDIAN OCEAN.

The British S. S. *Warrior* reports that on August 12th, when nearing Natal, South Africa, a full gale from a westerly direction was encountered, followed, after reaching port, by an unusually high barometer, reading 30.74 inches.

NORTH AMERICA.

Apparently there were no distinctive features in the weather of the current month. The temperature was above the normal for the season in the western plateau region of the United States as in the previous month; elsewhere it was close to normal. Precipitation in the United States was generally below the seasonal average, except along the immediate Atlantic coast, where heavy local downpours occurred. (See pp. 565–566 above.)

NORTH ATLANTIC OCEAN.

By F. A. YOUNG.

During August, 1919, there were, apparently, comparatively few cyclonic disturbances of marked intensity or extent over the North Atlantic Ocean, although not enough vessel reports were received in time to determine the conditions accurately over the northern steamer lanes, especially during the latter part of the month.

Judging from the observations received from land stations on the American and European coasts, as well as the Azores and Bermudas, it is evident that the mean pressure for the month differed but little from the normal, the departures ranging from $+0.04$ to -0.06, inches, approximately.

On August 2 there was a well-developed LOW off the New England coast; it moved rapidly northward, and by the morning of the 3d, was central near Cape Ray, Newfoundland, where the barometric reading was 29.40 inches. No heavy winds were reported on either of these dates, and on the 3d fog was prevalent on the Banks of Newfoundland. On the 9th there was an area of low pressure that occupied about the same territory, and of even less intensity than that of the 3d. From the 10th to the 13th the atmospheric circulation was comparatively sluggish, with slight gradients, the pressure being uniformly high north of the 40th parallel, and somewhat below the normal at the Azores and in the southern division of the ocean.

On the 14th (see Chart IX) a point about 200 miles east of the Virginia Capes was the center of a violent disturbance, although the storm area was of limited extent. Three vessels near the center experienced gales of from 40 to 65 miles an hour, and the observer on the American S. S. *Munrio* states in the storm log: "Gales began on the 13th, wind ESE. Lowest barometer 29.48 inches at 2 a. m. on the 14th, latitude 38°, longitude 74°. End of gale on the 14th, wind WNW. Highest force 65 miles per hour; shifts of wind near time of lowest barometer, backing from ESE. to NE." On the 15th there was a LOW of slight intensity central near Halifax, Nova Scotia; this moved rapidly eastward, and on the 17th the center was near latitude 50°, longitude 25°; light to moderate winds prevailed as a rule, although on the 17th one vessel in the easterly quadrant reported a moderate southerly gale. On the 18th the Danish S. S. *United States*, while near latitude 56°, longitude 22°, encountered a westerly gale of 50 miles an hour, accompanied by rain. The storm log is as follows: "Gale began on the 17th, wind WNW. Lowest barometer 28.56 inches at 5 p. m. on the 17th at latitude 58° 1′, longitude 16° 53′. Highest force of wind 90 miles per hour." Times of end of gale and shifts of wind not given. Unfortunately there

were no reports received north of the position of this vessel, and therefore it was impossible to locate the center of the LOW, although from the direction of the wind, the S. S. *United States* must have been well in the southern quadrants, especially as a number of vessels from 250 to 300 miles to the southward experienced light to moderate winds, with comparatively high barometic readings. From the 19th to the 25th there were no disturbances of any consequences over the ocean, although during part of that period a slight depression existed off the coast of northern Europe. On the 26th the Province of Quebec was surrounded by an area of low pressure of slight intensity, and on the same day a second LOW was central near Aberdeen, Scotland, where the barometric reading was 29.07 inches. Neither of these disturbances was accompanied by heavy weather, and light to moderate winds prevailed over the entire ocean. During the next two days the European LOW remained nearly stationary in position, gradually filling in. On the 28th reports were received from vessels not far from the French coast showing that moderate westerly gales prevailed in that section, although a number of other craft not far away encountered only moderate winds.

The number of days on which fog was reported was considerably below the normal on the Banks of Newfoundland and over the northern steamer lanes, while fog was somewhat more frequent than usual off the Virginia and North Carolina coasts, as well as in northern European waters.

NOTES ON WEATHER IN OTHER PARTS OF THE WORLD.

British Isles.—In August, as in the two preceding months, the rarity of thunderstorms formed a continuing feature in a manner which was characterized in other respects by a large amount of disturbed weather. The general rainfall, expressed as a percentage of the average, was as follows: England and Wales, 85; Scotland, 86; Ireland, 81; British Isles, 86.—*Symons's Meteorological Magazine, Sept., 1919, p. 93.*

France [1].—L'Orient, August 30, 1919. The coast of Brittany for miles north and south of here is strewn with wreckage thrown on shore during the great storm which prevailed yesterday. At Locqueltas a lifeboat and wreckage, apparently from an American merchant ship, was washed ashore. The name of the boat could not be deciphered. The storm is abating today.—*N. Y. Eve. Post, Aug. 30, 1919.*

Argentina.—Buenos Aires, August 12, 1919. Efforts to transport passengers over the trans-Andine mule train route again have been abandoned on account of snow. Only mails are now being carried across the mountains. —*Washington Eve. Star, Aug. 13, 1919.*

Australia.—Melbourne, August 27, 1919. Heavy rains have fallen over the wheat belt of New South Wales and Queensland, [breaking a drought and] giving promise of heavy crops from those sections of the country.—*N. Y. Eve. Post, Aug. 28, 1919;* [and *Hobart, Tas., Mercury, Aug. 20, 1919*].

[1] See also note published in MONTHLY WEATHER REVIEW, July, 1919, p. 501.

DETAILS OF WEATHER OF THE MONTH IN THE UNITED STATES.

CYCLONES AND ANTICYCLONES.

The great majority of the *cyclones* which traversed the North American continent passed eastward between the Great Lakes and Hudson Bay. A single cyclone moved northeastward along the Atlantic coast and gave rise to the heavy local downpours as noted in a previous paragraph. None of the cyclones was of unusual intensity.

Eight *anticyclones*, mostly of the Alberta type and four of the North Pacific type, moved east-southeast during the month. The number and movement of both cyclones and anticyclones was closely in accord with the normal expectation.

THE WEATHER ELEMENTS.

By P. C. DAY, Climatologist and Chief of Division.

[Dated: Weather Bureau, Washington, Oct. 1, 1919.]

PRESSURE AND WINDS.

The distribution of the mean atmospheric pressure over the United States and Canada, and the prevailing direction of the winds for August, 1919, are graphically shown on Chart VII, while the means at the several stations, with the departures from the normal, are shown in Tables I and III.

August, like the preceding month, was without marked fluctuations in atmospheric pressure, and the high and low areas were of the usual summer type, frequently without distinctive progressive movement. Moderately high pressure dominated northern districts east of the Rocky Mountains during the first few days of the month and again the latter part of the first and the early portion of the second decades. West of the Rockies, particularly near the Pacific coast, high pressure, usual to the summer season, prevailed almost continuously during the first half of the month, and it was only occasionally displaced in the latter half. During this period of the month in the districts to eastward of the Rocky Mountains pressure was highest over the southeastern States, although there was no marked change from the conditions normal to the period of the year.

Pressure was moderately low over southern districts during the early part of the month, although no distinctive storm center developed in that region until about the 12th, when falling pressure off the Florida coast indicated the development of a low area to the eastward, which, by the morning of the 13th, appeared as a storm of considerable energy off the Virginia coast. This storm moved to the Canadian maritime provinces within the following 48 hours, attended by high winds and local heavy rains along the immediate coast from the Carolinas to southern New England.

About the middle of the month low pressure moved into the northern border States to westward of Lake Superior, and during the following few days advanced eastward into New England and the Canadian maritime provinces, but lost energy as it approached the coast. This was quickly followed by another low area, which took a similar course and likewise dissipated as it moved toward the New England coast. The latter part of the month was without any material storm development, although near the close a considerable area of rain had overspread the districts to eastward of the Mississippi River.

The average pressure for the month was below the normal over a narrow area along the northern border from eastern Washington to Lake Superior and thence eastward to the Canadian maritime provinces and

southeastward to the middle Atlantic coast. Over all southern districts, and from the great central valleys westward to the Pacific, the average pressure for the month was below the normal; however, the departures both above and below were small in practically all cases.

In the absence of any well-defined storm areas, high winds were exceptional and few velocities above 50 miles per hour were recorded. This was particularly noticeable in the districts from the Mississippi Valley westward to the Pacific. The excess of pressure over southern districts favored a northward drift of the atmosphere, particularly from the Great Plains eastward, where winds with southerly components were the rule, save in portions of the upper Lakes and to the westward, where they were frequently from northerly and westerly points. In the mountain regions and thence west to the Pacific, westerly winds were prevalent, particularly where the direction was not influenced by local topography.

TEMPERATURE.

In the absence of any marked departure of the pressure distribution from that usual to a summer month, no great extremes of either warm or cool weather persisted for lengthy periods, and the month as a whole showed relatively small ranges in temperature.

The warmest period of the month in the great central valleys was about the middle of the first decade, at which time pressure was moderately high in the Gulf States and diminishing northward, thereby inducing warm southerly winds from the Gulf to the Canadian boundary. In the far western districts the warmest periods were generally after the middle of the month; in fact, the entire latter half of the month was decidedly warm in portions of California, particularly in the Great Valley, where the continued heat and drought forced the ripening of fruits, and the gathering of raisin grapes began 10 days to two weeks earlier than usual. In portions of the northern Rocky Mountains the warmest period of the month was at the close.

Cool weather prevailed over the Pacific coast districts at the beginning of the month and over the Northeastern States about the end of the first decade. Generally moderate temperatures prevailed throughout the second and the early part of the third decades, after which the coolest weather of the month occurred in most districts. Over the Southwestern States the 22d to 24th were the coolest days, while in the Southeastern States the 27th to 29th were quite cool. Over much of the Middle West the last two days of the month were the coolest.

Maximum temperatures were above 100° at some period of the month in practically all the States to westward of the Mississippi, and generally in the Central and Southern States to the eastward. In the Lake region and over the coast States from North Carolina to New England the maximum temperatures were somewhat less than 100°. The highest temperature reported during the month, 123°, was observed at Greenland Ranch, a station in one of the arid, depressed valleys of southeastern California. Temperatures of 110° and 113° were observed in the southern plains region and they were above 105° at points in the far Northwest.

The lowest temperature reported during the month was 14° at a point in the mountains of Montana, and temperatures below freezing were observed very generally throughout all the western mountain regions. To the eastward minimum temperatures below freezing were reported at exposed points in North Dakota, the upper Lake region, in the highlands of northern New York, and the interior of New England. Some light frosts were reported at exposed points in the more Northern States, but no damage occurred.

The average temperature for the month was not materially different from the normal in any section, but as a whole the month was warmer than that usually experienced in August over the greater part of the country. In certain States of the middle Plateau the average temperature for each of the five months, April to August, inclusive has been above normal.

PRECIPITATION.

The precipitation during the month was received mainly as local showers, resulting in large variations over restricted areas. The month opened with unsettled, rainy weather over the central and southern Mountain and Plateau regions, particularly in Arizona, where heavy falls were reported, and in the central and northern districts east of the Mississippi River. By the middle of the first decade rains had been rather frequent in north-central and eastern districts, and local showers had occurred in the middle Gulf States, particularly in western Florida, where about the 3d or 4th nearly 10 inches fell within 24 hours. Toward the latter part of the first decade showers were general over the upper Mississippi Valley and in the Middle Atlantic coast States and also at points in the South, Southwest, and Northwest, unusually heavy rains being reported from points in Colorado. Early in the second decade, heavy rains occurred over the east Gulf and portions of the Atlantic coast States, in connection with the northward movement of the only important low-pressure area that was observed during the month. At Savannah, Ga., a total of nearly 5 inches was measured within a period of two hours, the heaviest rate of fall ever experienced at that place. Farther north the same storm gave Atlantic City, N. J., a total of nearly 9 inches, the rate of fall at that place likewise being the greatest of record. At the same time well-distributed and generally copious rains occurred over the northern Plains, and extending eastward covered the upper Mississippi Valley, Lake region, Ohio Valley, and the adjacent regions eastward and southward.

The latter part of the second decade was marked by generally unsettled and showery weather east of the Great Plains with local heavy falls at widely scattered points.

At the beginning of the third decade rains were general in the eastern portion of the Plains States and over the Mississippi Valley, extending into most eastern districts by the morning of the 22d, with some heavy falls in eastern Texas and the lower Mississippi Valley. On the following day some heavy rain and thunderstorms occurred in the central portion of Arizona, much damage to standing crops and buildings being reported. The greater part of the last decade was without material precipitation to westward of the Mississippi, except about the 27th and 28th, when some heavy rains occurred in the Central Plains region. East of the Mississippi local rains were frequent in some of the Southern States during the last decade, and the last two or three days were generally rainy over the more eastern districts.

The monthly precipitation was heavy along the Atlantic coast and also over most of the Gulf States, where the amounts ranged generally from 4 to 12 inches, the largest monthly total, 16.7 inches, being reported from Pensacola, Fla. Over most districts from the middle

Plains eastward the rainfall was above 2 inches, and from 2 to 4 inches, or slightly more, occurred in portions of Arizona, New Mexico, and Colorado. The middle and northern portions of the western Plains region had little rain during the month, and there was a very general absence of any beneficial rain thence westward to the Pacific. At the end of the month severe drought still persisted in many parts of the far West and Northwest. In portions of southern Idaho and adjoining regions there has been no beneficial precipitation since May, and at some points the drought period has extended over a longer time than ever before known. As a result all vegetation, except where irrigated, is entirely dry, and the ranges afford no feed save at the higher elevations. Over most eastern districts the soil moisture at the end of the month was sufficient. In fact, over portions of the Gulf States the ground continued too wet throughout the entire month for proper cultivation of the soil, and considerable damage to crops resulted. In much of the Plains region and thence west to the Pacific, except in portions of the Southwest, the soil was everywhere exceedingly dry at the end of the month.

RELATIVE HUMIDITY.

From the upper Ohio Valley eastward and northeastward to the Atlantic coast and over the southern tier of States from ocean to ocean, the relative humidity was generally higher than normal, although the excess was small in practically all sections. In the central valleys and thence west to the Pacific coast the average humidity was nearly everywhere less than usual, the deficiency being quite large in localities where severe drought existed.

SEVERE STORMS.

The month was unusually free from extensive storm areas, and local thunderstorms were mostly without damaging winds. Some high winds were experienced along the middle Atlantic coast on the 13th and 14th, when corn was badly beaten down and fruit blown from trees. (See pp. 565–566.)

In Arizona severe storms were reported on the 23d and 30th, and much damage to buildings and crops was reported. Thunderstorms were frequent in New Mexico and some of them caused material damage.

Average accumulated departures for August, 1919.

Districts.	Temperature.			Precipitation.			Cloudiness.		Relative Humidity.	
	General mean for the current month.	Departure for the current month.	Accumulated departure since Jan. 1.	General mean for the current month.	Departure for the current month.	Accumulated departure since Jan. 1.	General mean for the current month.	Departure from the normal.	General mean for the current month.	Departure from the normal.
	°F.	°F.	°F.	In.	In.	In.	0-10		Perct.	
New England	65.5	−1.5	+14.4	4.01	+0.10	+1.01	5.9	+0.8	80	−1
Middle Atlantic	71.7	−0.9	+17.8	5.30	+0.80	−0.90	5.3	+0.2	76	−1
South Atlantic	78.3	+0.5	+ 8.2	5.15	−1.00	−1.30	5.8	+0.6	80	−2
Florida Peninsula	83.2	+0.7	− 2.9	2.94	−4.00	+6.10	5.5	+0.1	75	−4
East Gulf	79.8	+0.7	− 0.4	7.77	−0.30	+4.96	6.3	+1.2	83	+3
West Gulf	81.9	+0.9	− 8.5	3.22	+0.20	+2.50	4.3	+0.4	76	+1
Ohio Valley and Tennessee	74.0	−0.5	+ 9.4	3.54	+1.10	−1.10	4.8	+0.3	72	−1
Lower Lakes	68.7	−0.9	+17.1	3.96	+1.00	−0.30	5.4	+0.8	70	−2
Upper Lakes	66.9	+0.7	+27.0	2.04	−0.90	−3.00	4.9	+0.1	73	−3
North Dakota	68.7	+2.0	+27.2	1.80	−0.50	−1.85	3.1	−1.1	62	−5
Upper Mississippi Valley	72.5	−0.5	+17.9	2.60	−0.60	−0.80	3.9	−0.4	69	−2
Missouri Valley	74.8	−1.0	+18.9	3.09	−0.30	−3.00	4.0	−0.2	65	−2
Northern slope	69.2	+2.5	+24.1	0.51	−0.80	−3.80	3.7	−0.2	48	−7
Middle slope	77.7	+2.4	+ 7.7	1.72	−0.70	−3.90	3.9	0.0	58	+3
Southern slope	80.3	+1.0	−11.5	1.96	−0.20	−2.60	3.4	−0.4	61	−2
Southern Plateau	78.4	+1.1	+ 5.1	1.21	−0.01	+0.59	2.5	−1.1	46	+2
Middle Plateau	73.7	+0.2	+11.3	0.34	−0.50	−2.90	2.4	−0.6	32	−7
Northern Plateau	72.5	+2.6	+15.0	0.42	0.00	−2.90	2.8	+0.1	35	−7
North Pacific	62.3	+0.4	+ 8.8	0.12	−0.70	−4.70	4.7	+0.1	74	−2
Middle Pacific	65.0	+0.1	− 5.3	0.00	0.00	2.00	3.7	+0.4	59	−3
South Pacific	71.2	−0.1	+ 5.1	0.00	0.00	3.80	2.4	−0.2	66	+1

Winds of 50 mis./1 hr. (244 m./sec.) or more, during August, 1919.

Station.	Date.	Velocity.	Direction.	Station.	Date.	Velocity.	Direction.
Block Island, R. I.	14	56	ne.	Mount Tamalpais, Calif.	26	56	nw.
Cairo, Ill.	13	57	n.	Do.	27	78	nw.
Columbus, Ohio	16	53	nw.	Do.	28	76	nw.
Dayton, Ohio	16	57	w.	Nashville, Tenn.	31	50	w.
Ellendale, N. Dak.	12	52	n.	Norfolk, Va.	13	50	nw.
Evansville, Ind.	1	53	nw.	Point Reyes Light, Calif.	27	58	nw.
Do.	5	50	sw.	St. Joseph, Mo.	7	50	w.
Indianapolis, Ind.	20	50	sw.	St. Louis, Mo.	20	50	sw.
Do.	24	52	w.	Sandy Hook, N. J.	13	54	ne.
Lincoln, Nebr.	12	51	nw.	Do.	14	58	n.
Do.	4	70	nw.	Toledo, Ohio	30	53	w.
Little Rock, Ark.	14	52	w.	Topeka, Kans.	26	56	se.
Louisville, Ky.	20	54	w.	Trenton, N. J.	14	51	n.
Mount Tamalpais, Calif.	23	54	nw.	Valentine, Nebr.	3	56	w.
Do.	24	57	nw.				
Do.	25	52	nw.				

SPECIAL FORECASTS AND WARNINGS.

WEATHER AND CROPS.

WEATHER WARNINGS.

By R. HANSON WEIGHTMAN, Meteorologist.

[Dated: Weather Bureau, Washington, Sept. 5, 1919.]

SPECIAL FORECASTS.

Forecasts of wind and weather conditions at the surface and aloft were furnished daily to the Post Office Department and to several Army fields where special work is being carried on. The "Flying Weather" forecasts inaugurated during the month of July, 1919, for the use of the Air Service of the Army were made twice daily throughout the month. On August 10 the number of districts for which the forecasts were made was changed from 7 to 13, the present subdivisions corresponding to the geographical areas in use by the Weather Bureau. Special advises were transmitted daily by radio to the U. S. S. *Tern*, the U. S. S. *Brant*, and the U. S. S. *Partridge* while en route from Hampton Roads, Va., to Panama.

WASHINGTON FORECAST DISTRICT.

On August 8 there were strong indications of the development of a tropical disturbance in the Windward Islands near St. Lucia, as evidenced by a pressure reading of 29.78 inches at that place, showing a fall of 0.12 inch in 12 hours, and later in the day by a moderate sea swell from the south at Roseau, Dominica. The following message was sent to ports in the eastern Caribbean Sea:

Moderate tropical disturbance southeast of Porto Rico apparently moving slowly westward. Caution shipping interests.

On the same day advices were sent to points in the western Caribbean as follows:

Strong indications of tropical disturbance in eastern Caribbean Sea. It will move westward.

Information was also sent to Gulf and Atlantic ports and to the Navy Department for broadcasting to vessels at sea, as follows:

There are strong indications of tropical disturbance over eastern Caribbean Sea in approximately longitude 63° and latitude 14°. It will advance along a westerly course.

On the 9th the following message was given general distribution:

Tropical disturbance eastern Caribbean Sea. Approximate location latitude 15°, longitude 69°, moving westward. Intensity unknown. Caution advised vessels in Caribbean Sea.

Again on the 10th information was sent as follows:

Tropical disturbance in Caribbean Sea moving westward. Approximate position latitude 16°, longitude 74°. Intensity unknown. Caution advised vessels central and western Caribbean.

On the 11th the following information was disseminated:

Tropical disturbance in Caribbean Sea is moving westward in about latitude 15°. Apparently of slight intensity. Indications are that it will not pass into Gulf of Mexico.

The disturbance advanced westward, as indicated in the advices, and with decreasing intensity, for reports from land stations and scattered observations from vessels available at this time show no indication of its presence in the extreme western Caribbean. In its earlier stages it was of slight to moderate intensity. In a letter from R. Z. Kirkpatrick, chief hydrographer, Balboa Heights, Canal Zone, dated August 12, he states:

The special cablegrams of the 8th, 9th, 10th, and 11th, giving the progress of the hurricane, have been much appreciated by the Canal authorities, the shipping interests, and the 15th naval district. * * * A sea captain just in from New York reports that he passed through a moderate gale in the Caribbean on the 10th and 11th.

On the evening of the 12th there were some indications of a development on the Carolina coast (see Low No. 3), and moderate to fresh easterly winds were forecast for the middle Atlantic coast. On the following morning a disturbance was central off the Virginia coast with increasing intensity, and northeast-storm warnings were accordingly ordered at 10 a. m. from Delaware Breakwater to Boston, accompanied by the information that the disturbance would move northward with increased intensity. On the evening of the 13th the warnings were extended northward to Eastport, and on the 14th warnings were continued from New York to Eastport. Strong easterly winds and gales occurred along the coast.

On the 17th an advisory message for fresh, possibly strong, easterly winds was sent to Atlantic ports between Sandy Hook and Boston and winds of the character indicated occurred.

On the evening of the 20th advices for fresh to possibly strong west to northwest winds were sent to ports on Lake Superior and northern Lake Michigan, and on the 25th advices were sent for fresh to strong northwest winds on eastern Lake Superior, northern Lake Huron, and the eastern shore of northern Lake Michigan. Both of these advices were fully justified.

WARNINGS FROM OTHER DISTRICTS.

Chicago Forecast District.—No frost warnings were issued during the month, except for the cranberry marshes of Wisconsin on the 24th, 30th and 31st. The first of these warnings was not verified on account of decreasing pressure over the northern lake region during the night of the 24th–25th; the second warning was partially verified; the third was fully verified, except in northwestern Wisconsin. Light frost occurred at a few places on the 27th and 28th, for which no warnings were issued; however, no damaging temperature was registered at any point.

Special fire-weather forecasts have been telegraphed daily throughout the summer to the district forester at Missoula, Mont., who distributes them to forest rangers located at various points in Montana. This service has been of unusual importance on account of the abnormally hot, dry weather that has prevailed in Montana much of the summer and the consequent increased fire hazard.

Special forecasts were telegraphed to Springfield, Ill., on the 15th, 18th, and 20th in the interests of the State fair.—*Charles L. Mitchell.*

Denver Forecast District.—No general storm occurred in the district during the month. Thundershowers, with heavy rains in localities, occurred during the early days of the month in the eastern and southern parts of the dis-

trict, but unusually dry weather continued in Utah. Seasonable temperature prevailed generally. No special warnings were issued.—*Frederick W. Brist.*

New Orleans Forecast District.—No special warnings were issued and no general storm occurred without warnings. Local thundersqualls occurred on the Texas coast at Port Arthur on the 8th, and at Galveston on the 21st.—*I. M. Cline.*

San Francisco Forecast District.—August was a quiet month in this district with nearly normal temperatures in California, Washington, and northern Idaho. They were slightly above normal in Oregon, southern Idaho, and Nevada.

Rainfall in California, Nevada, and western Oregon was too light to be of benefit to vegetation or to mitigate the forest-fire hazard, which was acute in this territory during the entire month, and acute in Washington, Idaho, and eastern Oregon till the closing days of the month, when well-distributed showers occurred.

Fire-weather warnings were issued to some one or more parts of the district on 13 days, and practically all were verified.

There have been more forest fires this season than for a number of years, and there is now no question but that fire-weather warnings are of great assistance to the forest rangers. The following unsolicited testimonies regarding them were received during the month of August:

OREGON FOREST FIRE ASSOCIATION,
Portland, Oreg., August 14, 1919.

To loggers:

The United States Weather Bureau has instituted a telegraphic fire-weather warning service, which has been used by this association to great advantage. It has been found that their predictions of the coming or continuance of dry weather or high winds are of great value.

As you know, the especially dangerous portion of the fire season is now approaching.

We unqualifiedly recommend the Weather Bureau service, and should you desire to receive it will be glad to arrange this for you upon return of the inclosed postal card.

Very truly, yours,

HUGH HENRY, *Secretary.*

WASHINGTON FOREST FIRE ASSOCIATION,
Seattle, Wash., August 23, 1919.

Mr. E. A. BEALS,
District Forecaster, San Francisco, Calif.

Dear Mr. BEALS:

* * * * *

Your messages this year have been especially good and helpful to us. I wish to thank you again for the interest you have taken in our work.

Yours, very truly,

G. J. JOY, *Chief Fire Warden.*

No warnings other than fire-weather warnings were necessary, nor were they issued during the month.—*E. A. Beals.*

RIVERS AND FLOODS, AUGUST, 1919.

By ALFRED J. HENRY, Meteorologist in Charge.

At the end of July, 1919, many of the rivers of the Atlantic drainage south of Virginia were still in flood and so continued until about August 5, the crest of the flood, however, having occurred in the previous month.

Rather heavy rains in the lower Saluda, upper Congaree, and Edisto River basins of South Carolina on the 12th and 13th caused a sudden rise in those streams to flood stages. The Santee below Columbia being still high as a result of July floods, again passed flood stage in its lower reaches. Although the stages reached were several feet less than those of the previous month, light floods also occurred in the Flint and Ocmulgee Rivers of Georgia.

Excessive local rains on the headwaters of the Guadalupe on August 21 and 22 caused a flood in that river which had not subsided in the lower reaches at the close of the month. The estimated loss due to this flood was $8,000 in corn still standing in the fields.

The usual details follow:

TABLE I.—*Flood stages in the Atlantic drainage during the month of August, 1919.*

River and station.	Flood stage.	Above flood stages—dates.		Crest.	
		From—	To—	Stage.	Date.
	Feet.			*Feet.*	
Tar:					
Tarboro, N. C.	18	(*)	1	37.0	†27
Greenville, N. C.	13	(*)	5	24.5	†28
Neuse:					
Smithfield, N. C.	14	2	2	24.4	†24
Santee:					
Rimini, S. C.	12	(*)	3	23.3	†26
	12	13	23	15.6	17
Ferguson, S. C.	12	(*)	5	17.1	†27
	12	10	25	13.6	18
Saluda:					
Chappells, S. C.	14	13	13	17.0	13
Edisto:					
Edisto, S. C.	6	(*)	1	7.8	†26–28
	6	11	20	6.8	18
Ocmulgee:					
Abbeville, Ga.	11	(*)	3	14.5	†30
	11	15	16	11.3	16
Lumber City, Ga.	15	(*)	3	15.4	2
Flint:					
Albany, Ga.	20	(*)	2	23.4	1
	20	13	17	22.7	15

* Continued from July. † July.

TABLE II.—*Flood stages in the West Gulf drainage during the month of August, 1919.*

River and station.	Flood stage.	Above flood stages—dates.		Crest.	
		From—	To—	Stage.	Date.
	Feet.			*Feet.*	
Trinity:					
Trinidad, Tex.	28	(*)	1	32.4	†31
Gaudalupe:					
Gonzales, Tex.	22	26	27	25.6	26
Victoria, Tex.	16	27	(**)	20.5	30
Rio Grande:					
Rio Grande City, Tex.	15	(*)	2	22.6	†28
Gila:					
Kelvin, Ariz.	4	2	7	8.3	4

* Continued from July.
** Continued into September.
† July.

MEAN LAKE LEVELS DURING AUGUST, 1919.

By UNITED STATES LAKE SURVEY.

[Dated: Detroit, Mich., Sept. 4, 1919.]

The following data are reported in the "Notice to Mariners" of the above date:

Data.	Lakes.*			
	Superior.	Michigan and Huron.	Erie.	Ontario.
Mean level during August, 1919:	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Above mean sea level at New York	602.59	581.14	573.14	247.33
Above or below—				
Mean stage of July, 1919	+0.01	−0.20	−0.31	−0.42
Mean stage of August, 1918	+0.24	−0.62	+0.59	+0.90
Average stage for August, last 10 years	+0.03	+0.29	+0.52	+0.84
Highest recorded August stage	−1.34	−2.37	−0.97	−0.93
Lowest recorded August stage	+0.99	+1.29	+1.76	+2.98
Average relation of the August level to:				
July level	.....	±0.0	−0.2	−0.3
September level	.....	+0.2	+0.2	+0.4

* Lake St. Clair's level: In August, 575.92 feet.

EFFECT OF WEATHER ON CROPS, AUGUST, 1919.

By J. WARREN SMITH, Meteorologist in Charge.

Farm work.—August, 1919, was, on the whole, favorable for outdoor operations, except for the preparation of soil for winter grain seeding. This work made good progress from the upper Ohio Valley northeastward and in some north-central portions of the country, but in most other sections it was delayed by hard, dry soil. During the last few days of the month, however, the condition of the soil was improved by rain in many localities where drought had persisted, particularly in the eastern portions of Kansas and Nebraska, southern Missouri, and at places in the Ohio Valley, and this permitted better advance in the work of preparing seed beds for winter-grain sowing. There was some interruption to farm work in the Southern States by rain, especially during the last decade, but, otherwise, conditions were mostly favorable for farm work in that area.

Small grains.—August, 1919, was especially favorable for harvesting spring grains in the late districts and for thrashing both winter and spring grains in other sections of the country, except that thrashing was retarded by rain in the middle Atlantic States, parts of the upper Ohio Valley, and in some north-central districts about the middle of the month. Under the influence of rain and cooler weather early in the month, late spring grains in the higher elevations of the Rocky Mountain districts and in the far Northwest improved somewhat, but the rain came too late to be of material benefit to the early crops. As harvesting and thrashing of wheat progressed, the yields continued to show results below the previous expectations in both quantity and quality. The weather of the month was generally favorable for buckwheat in the Lake region and Appalachian Mountain districts, and this crop was in satisfactory condition at the close of the month in most sections where grown. Flax made satisfactory progress during August in the northern Great Plains; the harvest was in progress in South Dakota at the close of the month. Rice made favorable progress during the month in nearly all sections where grown; harvest and thrashing progressed favorably in the Gulf coast section, except for some delay by rain early in the third decade. Grain sorghums held up well in the southern Great Plains, despite the dry weather, and at the close of the month were in satisfactory condition; they had mostly headed out in Kansas.

Corn.—The rainfall early in August was very beneficial to corn in the upper Mississippi Valley and in parts of the Ohio Valley, but it continued too dry in the central Great Plains and portions of the extreme lower Missouri Valley. The crop in Iowa had mostly recovered from the previous drought by the close of the first decade of the month. During the last half of the month there was also decided improvement in Ohio, central and southern Indiana, and much of Illinois, while late corn had improved somewhat in the eastern parts of Nebraska, and Kansas, and in southern Missouri, but the rain came too late to be of material benefit to the crop in general in the last-named localities. Early corn developed satisfactorily in Oklahoma, but the late crop was damaged by drought in portions of that State. Corn matured rapidly during the latter part of the month, and at the close it was mostly out of danger from frost in the north-central border States.

Cotton.—Moderate temperatures prevailed throughout the month in the cotton belt, and rainfall, on the whole, was mostly moderate, except that it was fairly heavy to heavy in the east Gulf and South Atlantic States, where, in considerable areas, from 8 to 12 inches were received. Cotton made fairly satisfactory advance in most sections, except that it was generally poor in the southeastern and more eastern States. The condition of the crop at the close of the month continued unsatisfactory, however, except that it was fairly good in Oklahoma, western Texas, Arkansas, Tennessee, and in some restricted localities in other States. The condition was especially poor in much of Alabama, Georgia, and Florida. Insects continued active and damaging in many places, particularly in eastern Texas, Louisiana, and the central and southern parts of the east Gulf States.

Potatoes, truck, pastures, and fruit.—In many central, northern, and western districts the rainfall was insufficient, and it was too warm for good development of potatoes, and at the close of the month this crop was in only poor to fair condition in most sections, although there was some improvement in the Rocky Mountain districts and the Lake region, as a result of the rain the latter part of the month. Pastures and truck were favorably affected by the prevailing weather of the month in most of the Southern, Southwestern and Northeastern States, and in much of the north-central portion of the country, but in many central, western, and northwestern localities it was too dry and progress was unsatisfactory. The month was generally favorable for fruit, except for considerable dropping of apples in the northeastern part of the country, while the storm of the 13th blew much fruit from the trees in the northern Appalachian Mountain districts and Central Atlantic Coast States.

CLIMATOLOGICAL TABLES.*

CONDENSED CLIMATOLOGICAL SUMMARY.

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation, by sections, August, 1919.

Section.	Temperature.								Precipitation.					
	Section average.	Departure from the normal.	Monthly extremes.						Section average.	Departure from the normal.	Greatest monthly.		Least monthly.	
			Station.	Highest.	Date.	Station.	Lowest.	Date.			Station.	Amount.	Station.	Amount.
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	79.2	−0.4	Guin	103	7	Oneonta	51	27	7.55	+3.08	Citronelle	14.43	Guin	3.53
Arizona	79.5	+1.0	2 stations	118	13†	Fort Valley	41	5	2.23	−0.06	Ideal Ranger Station	5.04	Leupp	0.00
Arkansas	80.6	+1.3	Bee Branch	113	5	4 stations	55	19†	4.29	+0.50	Hope	10.24	Calico Rock	1.16
California	72.1	−0.7	Greenland Ranch	123	20	Portola	25	1	0.03	−2.05	Rose Mine	3.37	158 stations	0.00
Colorado	66.4	+1.8	Burlington	107	23	Dillon	25	22†	1.39	−0.50	Victor	3.98	Springfield	0.00
Florida	81.7	+0.4	Eustis	101	6	De Funiak Springs	60	29	6.67	−0.36	Pensacola	16.69	Key West	1.46
Georgia	78.9	−0.4	Rome	103	7	2 stations	52	27	5.81	+0.39	Leesburg	14.18	Gillsville	1.60
Hawaii (July)	74.2	+0.4	Mahukona	94	4	Glenwood	49	15	4.21	−1.05	Honomanu Valley	18.47	2 stations	0.00
Idaho	66.8	+2.4	Weiser	106	17†	Elk City	24	30	0.26	−0.24	Priest River	1.52	7 stations	0.00
Illinois	73.6	−0.4	2 stations	105	6	2 stations	44	10†	2.89	−0.46	Clinton	8.12	Aurora	0.35
Indiana	72.6	−0.6	Greencastle	103	7	La Porte	39	7	2.35	−0.97	Paoli	5.64	Dam No. 39	0.69
Iowa	71.5	−0.3	Clarinda	103	6	3 stations	38	31	2.59	−1.09	Maquoketa	5.72	Sioux Center	0.97
Kansas	78.3	+1.2	Minneapolis	111	6	Alton	45	31	1.91	−1.39	Ottawa	6.08	Hoxie	0.03
Kentucky	75.0	−0.7	Bowling Green	104	6	2 stations	47	28	3.49	−0.07	2 stations	6.98	Maysville	0.84
Louisiana	82.8	+1.1	Plain Dealing	104	8	Calhoun	62	31	5.11	−0.14	Plain Dealing	9.62	Melville	1.05
Maryland-Delaware	72.0	−1.4	Frederick, Md	96	24	Oakland, Md	39	29	6.06	+1.72	Denton, Md	12.99	Frederick, Md	1.66
Michigan	66.4	+0.5	Harrisville	97	7	Houghton Lake (near).	26	29	2.33	−0.50	Webber Dam	4.26	Cooke Site	0.39
Minnesota	67.2	+0.5	Beardsley	99	14	3 stations	32	27†	3.11	−0.47	Winnibigoshish	10.08	Tyler	0.15
Mississippi	81.2	+0.9	3 stations	105	7	Okolona	57	31	6.23	+1.81	Meridian	12.10	Crenshaw	1.29
Missouri	75.7	−0.5	Caruthersville	106	6†	Bethany	44	31	4.29	+0.49	Lamonte	11.27	Springfield	0.53
Montana	67.1	+2.7	Glasgow	104	31	Bowen	14	29	0.62	−0.59	Outlook	1.95	Virginia City	0.00
Nebraska	73.3	+0.5	2 stations	106	3	Gordon	33	30	1.51	−1.27	Schuyler	6.86	Scottsbluff	0.09
Nevada	72.6	+3.9	2 stations	111	14†	2 stations	32	2†	0.09	−0.29	Searchlight	0.98	16 stations	0.00
New England	64.7	−2.1	Bridgeport, Conn	92	24	Somerset, Vt	24	9	3.91	+0.07	Bridgeport, Conn	9.50	Houlton, Me	0.46
New Jersey	70.0	−2.0	Clayton	98	24	Charlotteburg	38	30	6.89	+2.23	Woodbine	12.88	Layton	3.09
New Mexico	71.3	+0.8	Artesia	110	15	Elizabethtown	31	23	1.81	+0.66	Batemans Ranch	4.82	Lakewood	0.00
New York	65.8	−1.5	West Point	100	29	Gabriels	25	9	3.84	+0.10	Searsdale	8.16	Morrisville	0.65
North Carolina	75.1	−0.2	Caroleen	99	7	2 stations	42	27	3.98	−1.96	Gorge	10.09	Marshall	1.15
North Dakota	67.8	+2.4	2 stations	101	19	Hannah	30	27	1.62	−0.66	Hillsboro	5.65	Bierman	0.04
Ohio	70.5	−1.1	2 stations	99	5	Haydenville	39	28	4.46	+1.55	Norwalk	9.23	Xenia	0.72
Oklahoma	82.3	+1.4	2 stations	110	6†	Beaver	50	24†	3.17	−0.16	Broken Bow	9.10	Hooker	0.25
Oregon	67.4	+1.6	Grants Pass	106	15	Fremont	22	22	0.14	−0.37	Government Camp	0.80	14 stations	0.00
Pennsylvania	68.2	−1.7	4 stations	94	5†	2 stations	35	9†	5.43	+1.33	Lycippus	12.03	Girardville	2.35
Porto Rico	79.1	−0.1	3 stations	96	6†	Juncos	59	22	3.64	−3.86	Coloso	15.98	Isidora	0.10
South Carolina	78.5	−0.4	Santuck	103	8	Landrum	53	27	5.08	−0.99	St. George	9.69	Effingham	1.44
South Dakota	70.9	+0.8	3 stations	105	5†	Cottonwood	34	24	0.93	−1.56	Tyndall	3.21	Greenmont	0.03
Tennessee	76.9	+0.5	Brownsville	104	7	Mountain City	42	26	5.15	+1.17	Waynesboro	10.74	Memphis	0.82
Texas	82.1	−0.4	Midland	111	16	Dalhart	53	23†	3.44	+1.03	Kerrville	14.34	3 stations	0.00
Utah	71.0	+2.2	St. George	100	24	Black's Fork	27	12†	0.88	−0.14	Monticello	2.60	2 stations	0.00
Virginia	72.7	−1.4	2 stations	98	7†	Burkes Garden	39	28	2.88	−1.35	Warsaw	5.57	Hawfield	0.58
Washington	66.0	+0.9	Trinidad	105	18	Wilbur	29	31	0.34	−0.50	Snoqualmie Pass	1.70	6 stations	0.00
West Virginia	70.2	−1.7	2 stations	100	5†	Brandywine	40	29	4.54	+0.75	Camden-on-Gauley	8.67	Upper Tract	0.95
Wisconsin	66.7	−0.1	Delavan	97	4	Big St. Germain Dam.	31	9	2.67	−0.72	Spooner	5.36	Madison	0.89
Wyoming	65.8	+1.8	Clermont	102	31	Moran	20	30	0.42	−0.69	2 stations	1.40	3 stations	0.00

* For explanation of the following tables and charts, see this REVIEW, January, 1919, pp. 52–53.

† Other dates also.

TABLE I.—*Climatological data for Weather Bureau Stations, August, 1919.*

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.														Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity.	Precipitation.			Wind.					Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow on ground at end of month.
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max.+mean min.÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.									Total.	Departure from normal.	Days with 0.01 inch or more.	Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Maximum velocity. Direction.	Maximum velocity. Date.						
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	° *F.*	° *F.*	°*F*		°*F*	°*F*		°*F*	°*F*						°*F*	°*F*	%	*In.*	*In.*		*Miles*					*0–10*	*In.*	*In.*
New England.							**65.5**	**– 1.5**															**80**	**4.01**	**+ 0.1**								**5.9**		
Eastport	76	67	85	29.85	29.93	– .03	58.2	– 1.5	79	23	65	47	10	51	27						55	53	87	2.98	– 0.3	10	5,751	s.	32	se.	30	6	10	15	6.7	.....	.....
Greenville, Me	1,070	6	....	28.78	29.94	.....	60.8	.....	81	21	70	39	12	51	35						.....	.....	.....	3.71	.....	18	.....	.....	.....	.....	.....	7	12	12	.....	.....	.....
Portland, Me	103	82	117	29.83	29.95	– .03	64.0	– 2.2	83	8	71	49	28	57	25						59	56	78	1.85	– 1.7	13	5,728	s.	32	ne.	14	8	13	10	5.7	.....	.....
Concord	288	70	79	29.64	29.95	– .03	64.7	– 1.9	84	5	76	39	10	54	38						.....	.....	.....	1.60	– 2.1	12	2,998	nw.	26	nw.	24	11	11	9	5.3	.....	.....
Burlington	404	11	48	29.49	29.91	– .06	65.0	– 1.1	87	5	74	46	12	56	30						.....	.....	.....	2.91	– 1.1	14	6,441	s.	30	s.	17	3	10	18	7.1	.....	.....
Northfield	876	12	60	.....	29.95	– .03	61.5	– 1.4	82	5	72	37	12	50	41						.....	.....	80	2.40	– 1.5	16	4,661	s.	30	s.	30	2	15	14	.....	.....	.....
Boston	125	115	188	29.81	29.94	– .05	68.8	– 0.1	90	24	76	55	10	61	24		62	58	72		5.07	+ 1.0	11	6,732	w.	28	s.	30	8	13	10	6.1	.....	.....
Nantucket	12	14	90	29.94	29.95	– .04	67.0	– 1.0	82	23	73	56	17	61	18		63	61	87		7.17	+ 4.1	13	10,265	sw.	49	e.	14	10	9	12	5.7	.....	.....
Block Island	26	11	46	29.92	29.95	– .04	66.9	– 1.8	81	24	72	58	15	62	17		64	62	88		4.87	+ 1.4	11	10,590	sw.	56	ne.	14	10	6	15	6.5	.....	.....
Providence	160	215	251	29.78	29.95	– .04	67.9	– 3.1	91	24	76	52	10	60	27		62	58	75		5.14	+ 1.1	10	7,879	nw.	36	nw.	2	11	11	9	5.4	.....	.....
Hartford	159	122	140	29.77	29.94	– .05	68.0	– 0.9	91	24	76	51	10	59	27		62	59	77		3.05	– 1.5	12	4,731	sw.	27	se.	17	7	11	13	6.0	.....	.....
New Haven	106	117	155	29.84	29.95	– .04	68.6	– 1.5	91	24	76	53	28	61	24		63	59	74		7.02	+ 2.0	14	5,973	sw.	34	ne.	14	16	6	9	4.9	.....	.....
Middle Atlantic States.							**71.7**	**– 0.9**															**76**	**5.30**	**+ 0.8**								**5.3**		
Albany	97	102	115	29.83	29.93	– .05	68.3	– 1.2	88	24	77	52	10	60	27		62	59	76		4.60	+ 0.6	11	4,258	s.	23	sw.	19	15	8	8	4.8	.....	.....
Binghamton	871	10	69	29.02	29.94	– .05	66.2	– 1.3	88	7	76	45	10	56	32						.....	.....	.....	2.95	– 0.4	11	3,328	ne.	28	nw.	24	7	11	13	6.4	.....	.....
New York	314	414	454	29.61	29.94	– .06	70.2	– 2.2	89	24	77	56	14	63	23		63	60	74		7.74	+ 3.2	11	10,672	nw.	40	ne.	14	7	13	11	5.9	.....	.....
Harrisburg	374	94	104	29.57	29.96	– .05	71.0	– 1.1	89	24	80	54	28	62	25		63	59	71		4.07	– 0.2	11	3,630	w.	21	n.	8	13	7	11	5.2	.....	.....
Philadelphia	117	123	190	29.83	29.95	– .05	73.3	– 0.5	92	24	81	59	14	66	24		66	63	73		6.19	+ 1.6	10	6,345	nw.	47	ne.	14	9	14	8	5.3	.....	.....
Reading	325	81	98	29.61	29.95	.....	70.8	.....	90	24	80	54	29	62	27		64	60	73		7.51	+ 3.0	12	4,133	se.	31	sw.	21	12	6	13	5.4	.....	.....
Scranton	805	111	119	29.12	29.97	– .03	67.6	– 1.7	88	24	77	47	9	58	30		61	58	77		2.30	– 2.0	13	4,488	n.	23	sw.	24	5	11	15	6.5	.....	.....
Atlantic City	52	37	48	29.89	29.94	– .06	72.0	– 0.6	91	24	78	58	26	66	26		67	64	80		11.57	+ 7.3	15	4,999	sw.	39	ne.	13	11	11	9	4.8	.....	.....
Cape May	18	13	49	29.96	29.98	– .02	73.4	0.0	92	24	80	59	9	67	23		68	66	83		12.60	+ 8.3	14	4,370	sw.	35	e.	13	14	8	9	4.6	.....	.....
Sandy Hook	22	10	57	29.92	29.94	.....	71.1	.....	89	24	77	59	29	65	20		66	63	79		5.76	.....	11	9,908	sw.	58	n.	14	9	14	8	5.4	.....	.....
Trenton	190	159	183	29.74	29.94	.....	70.6	.....	90	24	79	55	28	62	26		64	61	76		4.82	– 0.8	11	6,786	w.	51	n.	14	6	16	9	5.8	.....	.....
Baltimore	123	100	113	29.83	29.96	– .05	74.6	– 0.1	94	24	83	58	13	66	25		67	63	72		6.45	+ 2.2	9	4,432	sw.	29	sw.	21	12	12	7	4.7	.....	.....
Washington	112	62	85	29.84	29.95	– .06	73.6	– 0.9	93	24	83	55	10	64	27		66	63	75		3.41	– 1.0	10	3,874	nw.	26	nw.	13	12	12	7	4.9	.....	.....
Lynchburg	681	153	188	29.25	29.98	– .04	73.9	– 0.9	92	5	84	52	27	64	29		66	63	74		3.03	– 1.2	10	3,848	w.	36	ne.	5	13	10	2	4.7	.....	.....
Norfolk	91	170	205	29.88	29.97	– .03	76.6	– 0.1	93	24	84	59	27	69	24		69	66	76		3.47	– 2.5	13	8,567	sw.	50	nw.	13	9	18	4	4.7	.....	.....
Richmond	144	11	52	29.82	29.97	– .04	75.0	– 0.5	92	24	85	53	27	65	28		68	66	78		2.62	– 1.8	11	4,641	sw.	30	nw.	13	8	12	11	6.1	.....	.....
Wytheville	2,293	49	55	27.68	29.99	– .02	68.6	– 0.9	90	7	79	47	27	58	29		62	59	78		1.40	– 3.1	13	3,932	w.	21	w.	21	12	11	8	4.9	.....	.....
South Atlantic States.							**78.3**	**+ 0.5**															**80**	**5.15**	**– 1.0**								**5.8**		
Asheville	2,255	70	84	27.73	30.02	.00	71.1	+ 0.6	91	7	81	50	27	62	28		64	61	79		1.77	– 3.0	13	4,164	nw.	26	se.	11	6	17	8	5.4	.....	.....
Charlotte	773	153	161	29.18	29.99	– .03	77.0	+ 0.4	94	8	86	60	27	68	25		69	66	77		3.94	– 1.6	7	2,926	sw.	20	n.	31	1	21	9	7.0	.....	.....
Hatteras	11	12	50	29.97	29.98	– .02	78.6	+ 0.4	89	24	84	68	4	73	17		73	70	79		1.27	– 4.6	8	10,290	sw.	43	w.	13	8	17	6	5.3	.....	.....
Raleigh	376	103	110	29.59	29.98	– .03	76.9	+ 0.1	93	8	86	60	3	67	24		69	66	75		4.88	– 1.0	12	5,079	sw.	31	w.	31	10	12	9	5.3	.....	.....
Wilmington	78	81	91	29.92	30.00	.00	78.3	+ 0.3	95	1	86	64	3	70	20		72	70	82		5.52	– 1.0	10	4,972	sw.	20	e.	12	9	18	4	4.6	.....	.....
Charleston	48	11	92	29.96	30.01	.00	81.0	+ 0.7	97	1	88	67	13	74	19		74	72	78		5.70	– 1.3	11	6,564	sw.	29	se.	11	7	12	12	5.7	.....	.....
Columbia, S. C	351	41	57	29.64	30.01	.00	78.8	+ 0.7	95	7	88	63	27	70	24		70	68	78		5.70	– 1.1	11	3,981	sw.	39	sw.	14	5	11	15	6.4	.....	.....
Augusta	180	62	77	29.80	30.00	– .01	79.6	+ 0.7	95	1	88	62	27	71	26		72	70	81		2.89	– 2.7	9	3,528	s.	31	sw.	21	6	11	14	6.5	.....	.....
Savannah	65	150	194	29.95	30.02	+ .01	80.4	+ 1.0	94	1	88	65	13	72	25		74	73	86		12.86	+ 5.4	12	7,059	sw.	36	n.	19	4	13	14	6.7	.....	.....
Jacksonville	43	200	245	29.99	30.04	+ .03	81.5	+ 1.4	94	21	89	68	17	74	20		75	74	83		6.96	+ 0.8	16	7,455	sw.	45	nw.	17	11	17	3	4.8	.....	.....
Greenville, S. C	1,013	113	122	28.92	29.99	.....	76.2	.....	93	8	85	61	27	68	24		68	66	78		4.34	.....	13	4,878	w.	46	n.	1	4	18	9	6.3	.....	.....
Florida Peninsula.							**83.2**	**+ 0.7**															**75**	**2.94**	**– 4.0**								**5.**		
Key West	22	10	64	30.01	30.04	+ .06	84.2	+ 0.4	92	28	89	75	24	79	15		77	74	73		1.46	– 3.2	12	5,859	se.	31	se.	11	15	13	3	4.2	.....	.....
Miami	25	71	79	30.04	30.07	.....	82.6	+ 0.6	92	2	88	72	11	77	16		76	74	75		3.73	– 3.9	12	4,875	se.	37	sw.	12	4	19	8	5.7	.....	.....
Tampa	35	79	92	30.02	30.05	+ .05	82.7	+ 1.2	95	21	90	70	31	75	20		75	73	78		3.63	– 5.0	13	3,545	sw.	28	sw.	31	4	14	13	6.5	.....	.....
East Gulf States.							**79.8**	**+ 0.7**															**83**	**7.77**	**– 0.3**								**6.3**		
Atlanta	1,174	190	216	28.82	30.03	+ .02	76.4	+ 0.3	94	7	84	64	27	68	24		70	68	80		3.80	– 0.7	16	6,473	w.	42	w.	18	5	7	19	7.1	.....	.....
Macon	370	78	87	29.63	30.02	+ .01	78.8	+ 0.6	95	6	88	61	27	70	26		72	70	82		4.98	+ 0.7	15	3,178	sw.	27	w.	21	7	7	17	6.3	.....	.....
Thomasville	273	49	58	29.74	30.03	+ .03	80.8	– 0.1	94	29	90	66	13	72	24		73	71	85		8.16	+ 3.1	15	2,502	sw.	20	sw.	22	4	18	9	6.0	.....	.....
Pensacola	56	140	182	29.97	30.03	+ .05	80.1	– 0.9	93	2	86	69	30	74	17		74	73	82		16.69	+ 9.5	20	7,368	w.	49	nw.	7	5	12	14	6.5	.....	.....
Anniston	741	9	57	29.26	30.04	+ .05	77.9	+ 1.5	97	7	88	56	27	68	28		.....	.....	.....		4.26	– 0.2	12	2,990	s.	19	sw.	18	7	16	8	5.4	.....	.....
Birmingham	700	11	48	29.29	30.04	+ .05	78.6	– 1.2	98	7	88	61	31	69	25		71	69	83		5.33	+ 0.8	15	3,385	s.	23	se.	19	6	13	12	6.0	.....	.....
Mobile	57	125	161	29.97	30.03	+ .04	81.9	+ 2.2	98	7	90	69	31	74	23		75	73	83		6.04	– 0.8	17	5,702	sw.	37	ne.	14	7	12	12	6.2	.....	.....
Montgomery	223	100	112	29.79	30.03	+ .04	79.9	+ 0.2	97	7	88	66	27	71	24		73	71	83		8.46	+ 4.2	11	3,585	s.	28	n.	8	8	7	16	6.5	.....	.....
Meridian	375	85	93	29.63	30.02	+ .04	79.6	+ 1.1	94	7	88	66	31	71	25		73	72	85		12.10	+ 8.6	18	3,052	sw.	26	n.	18	7	13	11	5.9	.....	.....
Vicksburg	247	65	74	29.75	30.02	+ .04	81.4	+ 1.8	95	7	90	65	31	73	23		74	72	82		8.26	+ 4.7	11	4,013	sw.	26	ne.	8	2	19	10	6.3	.....	.....
New Orleans	51	76	84	29.97	30.02	+ .04	83.2	+ 2.2	96	7	90	70	24	76	21		77	76	84		7.38	+ 1.8	16	3,720	sw.	28	ne.	30	4	13	14	6.9	.....	.....
West Gulf States.							**81.9**	**+ 0.9**															**76**	**3.22**	**+ 0.2**								**4.3**		
Shreveport	249	77	93	29.75	30.01	+ .04	82.6	+ 1.2	98	13	92	69	31	74	23		74	72	78		3.85	+ 1.6	11	4,220	sw.	28	s.	20	19	4	8	4.1	.....	.....
Bentonville	1,303	11	44	28.65	29.98	+ .01	77.2	+ 0.7	97	2	88	55	31	66	30		.....	.....	.....		2.95	– 1.1	7	2,767	s.	18	w.	15	18	8	5	3.6	.....	.....
Fort Smith	457	79	94	29.50	29.96	– .01	82.4	+ 3.0	104	6	93	66	18	72	31		72	68	68		4.92	+ 1.3	9	4,570	e.	46	sw.	17	16	10	5	3.9	.....	.....
Little Rock	357	139	147	29.62	29.99	+ .01	81.0	+ 1.8	99	7	90	65	31	72	24		72	68	70		3.45	– 0.2	10	5,430	sw.	52	w.	14	14	12	5	4.5	.....	.....
Brownsville	57	4	26	.....	.....	.....	86.2	.....	102	31	96	74	2	76	28		.....	.....	.....		0.25	.....	1	.....	se.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Corpus Christi	20	69	77	29.99	30.01	+ .08	83.1	+ 3.0	96	31	89	74	31	77	22		77	52	82		0.13	– 2.2	3	9,655	se.	35	se.	20	16	8	7	4.3	.....	.....
Dallas	512	109	117	29.45	29.98	.....	82.6	– 0.3	99	7	91	70	30	74	25		.....	.....	.....		4.02	.....	9	5,637	s.	25	nw.	9	19	3	7	3.6	.....	.....
Fort Worth	670	106	114	29.25	29.96	+ .02	82.0	– 0.6	100	7	92	66	30	72	27		73	70	74		5.00	+ 3.1	8	6,398	s.	29	s.	21	18	3	8	4.2	.....	.....
Galveston	54	106	114	29.97	30.03	+ .07	83.4	+ 0.8	91	8	88	71	31	78	18		77	75	79		2.17	– 2.8	10	6,512	s.	41	se.	21	11	15	5	4.6	.....	.....
Houston	138	111	121	29.84	30.01	.....	83.6	+ 0.7	96	17	92	71	18	75	24		.....	.....	.....		3.82	.....	11	4,349	s.	25	ne.	25	10	14	7	4.9	.....	.....
Palestine	510	64	72	29.84	30.00	+ .03	81.2	+ 0.7	97	8	90	67	19	72	29		73	71	80		3.36	+ 1.1	7	4,299	sw.	39	ne.	8	16	8	7	4.6	.....	.....
Port Arthur	34	58	66	29.97	30.01	.....	82.2	.....	94	7	89	70	26	75	22		76	75	84		6.32	.....	13	5,197	sw.	45	se.	8	8	12	11	5.7	.....	.....
San Antonio	701	119	132	29.28	29.99	+ .06	82.2	+ 0.2	96	8	92	70	26	73	25		73	70	76		2.14	– 0.6	7	4,809	se.	30	sw.	22	16	10	5	3.9	.....	.....
Taylor	582	55	63	29.42	30.03	+ .08	81.5	– 0.2	96	8	91	68	21	72	25		.....	.....	.....		4.27	+ 1.8	9	5,035	s.	27	s.	21	8	16	7	5.3	.....	.....

TABLE I.—*Climatological data for Weather Bureau Stations, August, 1919*—Continued.

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.										Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity.	Precipitation.			Wind.					Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow on ground at end of month.
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max.+mean min.÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.					Total.	Departure from normal.	Days with 0.01 inch or more.	Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Maximum velocity. Direction.	Maximum velocity. Date.						
Ohio Valley and Tennessee.	*Ft.*	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	*° F.*	*° F.*	*° F*		*° F*	*° F*		*° F*	*° F*		*° F*	*° F*	*%*	*In.*	*In.*		*Miles*								*0–10*	*In.*	*In.*
							74.0	− 0.5											72	3.54	+ 1.1									4.8		
Chattanooga	762	189	213	29.23	30.02	+ .02	77.5	+ 1.0	98	7	86	59	27	69	24		69	66	74	4.71	+ 1.0	13	5,366	w.	37	e.	7	6	13	12	6.1	.....	.....
Knoxville	996	102	111	28.97	30.00	.00	76.0	+ 1.3	95	7	85	60	27	67	26		68	65	77	4.67	+ 0.7	15	4,056	sw.	30	s.	17	7	17	7	5.6	.....	.....
Memphis	399	76	97	29.61	30.03	+ .05	80.4	+ 1.2	97	7	88	64	31	72	23		72	69	72	0.82	− 2.4	10	5,707	sw.	30	sw.	29	18	7	6	3.9	.....	.....
Nashville	546	168	191	29.44	30.01	+ .01	77.6	− 0.2	98	6	86	60	31	69	26		69	65	72	6.80	+ 3.3	11	5,328	w.	50	w.	31	10	14	7	4.9	.....	.....
Lexington	989	193	230	28.95	30.00	− .01	73.5	− 1.1	91	6	82	58	9	65	29		.....	.....	.....	2.39	− 1.2	8	8,091	sw.	42	nw.	20	16	9	6	3.8	.....	.....
Louisville	525	219	255	29.43	30.00	.00	75.8	− 0.7	94	6	85	60	11	66	27		67	62	69	1.57	− 1.9	6	7,247	sw.	54	w.	20	20	4	7	3.6	.....	.....
Evansville	431	139	175	29.54	30.00	+ .01	77.2	+ 0.2	98	6	87	59	31	67	26		67	62	66	2.49	− 0.8	11	6,786	sw.	53	nw.	1	9	18	4	4.4	.....	.....
Indianapolis	822	194	230	29.11	29.98	− .02	73.4	− 0.2	95	6	83	55	31	64	25		64	59	67	3.43	+ 0.1	10	7,285	sw.	52	w.	24	12	16	3	4.1	.....	.....
Terre Haute	575	96	129	29.36	29.97	.....	74.2	.....	97	4	85	54	31	64	30		64	59	65	1.30	.....	8	6,079	sw.	33	nw.	6	8	20	3	4.6	.....	.....
Cincinnati	628	11	51	29.32	29.98	− .03	73.2	+ 1.6	94	15	84	52	29	62	30		64	59	67	0.92	− 2.4	10	4,750	sw.	29	nw.	24	15	12	4	4.9	.....	.....
Columbus	824	173	222	29.12	29.98	− .03	70.6	− 2.4	91	5	80	52	10	61	27		63	59	70	3.71	+ 0.5	13	7,402	sw.	53	nw.	16	9	15	7	4.9	.....	.....
Dayton	899	181	216	29.01	29.94	.....	71.5	− 2.1	93	15	81	53	28	62	31		63	59	71	3.12	+ 0.1	11	6,092	sw.	57	w.	16	14	13	4	3.9	.....	.....
Pittsburgh	842	353	410	29.08	29.97	− .04	70.0	− 2.5	88	16	78	53	10	62	27		62	58	71	7.15	+ 4.0	17	6,978	sw.	49	nw.	5	7	12	12	5.7	.....	.....
Elkins	1,940	41	50	27.99	29.99	− .03	66.4	− 2.0	88	16	77	45	29	56	32		61	59	85	3.09	− 0.6	15	2,967	w.	26	w.	18	7	11	13	6.4	.....	.....
Parkersburg	638	77	82	29.35	30.00	− .01	72.4	− 0.9	94	7	82	50	28	62	33		64	61	73	4.60	+ 1.1	13	3,629	sw.	30	w.	17	11	9	11	5.7	.....	.....
Lower Lake Region.							68.7	− 0.9											70	3.96	+ 1.0									5.4		
Buffalo	767	247	280	29.12	29.93	− .06	66.9	− 1.9	86	16	73	52	25	61	21		61	57	74	3.04	0.0	12	10,488	sw.	46	nw.	25	5	11	15	6.5	.....	.....
Canton	448	10	61	29.42	29.89	.....	65.3	− 2.5	85	21	74	39	9	56	31		.....	.....	.....	2.60	− 0.1	15	6,138	sw.	38	sw.	21	10	10	11	5.4	.....	.....
Oswego	335	76	91	29.55	29.91	− .08	66.4	− 2.4	88	7	73	51	10	60	22		61	58	76	4.14	+ 1.4	12	6,546	sw.	27	ne.	1	7	9	15	6.1	.....	.....
Rochester	523	97	113	29.38	29.94	− .05	67.8	− 0.5	91	7	76	52	10	59	24		60	56	72	3.60	+ 0.6	12	5,552	sw.	31	w.	16	8	13	10	5.7	.....	.....
Syracuse	597	97	113	29.31	29.94	− .05	66.6	− 2.0	87	7	74	50	9	59	23		.....	.....	.....	2.00	− 1.3	13	6,837	sw.	34	sw.	24	6	15	10	5.9	.....	.....
Erie	714	130	166	29.18	29.94	− .06	69.2	− 0.7	88	16	76	54	27	62	26		62	57	70	4.64	+ 1.4	14	9,321	s.	42	se.	13	5	19	7	5.7	.....	.....
Cleveland	762	190	201	29.14	29.95	− .06	69.8	− 0.6	86	15	77	55	27	63	22		62	58	68	7.19	+ 4.0	12	8,835	s.	48	w.	30	10	16	5	5.3	.....	.....
Sandusky	629	62	103	29.27	29.94	− .07	71.2	− 0.3	91	5	80	53	28	63	27		.....	.....	.....	5.37	+ 2.0	13	7,690	sw.	42	w.	30	5	19	7	5.4	.....	.....
Toledo	628	208	243	29.28	29.96	− .04	70.9	00	90	5	80	52	28	61	28		62	57	68	4.54	+ 1.8	10	8,756	sw.	53	w.	30	16	12	3	4.0	.....	.....
Fort Wayne	856	113	124	29.06	29.97	.....	71.2	+ 0.2	95	4	82	53	28	61	29		62	57	66	1.61	.....	8	5,952	sw.	27	nw.	5	10	18	3	4.5	.....	.....
Detroit	730	218	245	29.17	29.95	− .06	70.2	+ 0.3	89	23	79	52	26	61	26		61	56	67	2.49	− 0.3	9	7,194	w.	36	sw.	21	9	18	4	4.8	.....	.....
Upper Lake Region.							66.9	+ 0.7											73	2.04	− 0.9									4.9		
Alpena	609	13	92	29.26	29.92	− .08	64.5	+ 0.7	86	23	73	43	29	56	30		60	57	77	2.53	− 0.8	9	7,856	nw.	33	nw.	25	3	14	14	6.2	.....	.....
Escanaba	612	54	60	29.27	29.92	− .07	64.6	+ 0.1	84	15	73	44	9	56	29		59	56	76	2.49	− 1.1	7	6,184	s.	27	n.	7	11	15	5	4.5	.....	.....
Grand Haven	632	54	89	29.27	29.93	− .06	67.0	− 0.8	82	22	74	47	29	60	29		62	59	74	1.49	− 1.1	11	7,407	w.	32	w.	21	17	8	6	3.9	.....	.....
Grand Rapids	707	70	87	29.19	29.93	− .07	69.8	− 0.2	89	23	80	50	29	60	31		61	56	66	1.67	− 0.9	11	3,923	nw.	24	nw.	26	10	15	6	4.7	.....	.....
Houghton	684	62	99	29.17	29.89	− .08	65.0	+ 1.7	87	19	73	48	8	57	31		.....	.....	.....	2.28	− 0.6	8	7,077	w.	35	w.	21	8	10	13	6.2	.....	.....
Lansing	878	11	62	29.02	29.94	.....	67.3	− 1.3	87	23	79	45	29	55	36		61	58	78	4.03	+ 1.4	10	3,301	sw.	18	nw.	25	7	20	4	5.2	.....	.....
Ludington	637	60	66	29.25	29.94	.....	66.0	.....	80	12	72	47	9	60	25		61	57	74	1.47	.....	10	6,616	s.	30	nw.	29	16	10	5	3.7	.....	.....
Marquette	734	77	111	29.15	29.92	− .06	65.2	+ 1.7	85	20	72	47	9	58	29		60	56	74	1.60	− 1.3	12	7,451	w.	35	sw.	20	5	14	12	6.5	.....	.....
Port Huron	638	70	120	29.25	29.94	− .06	67.4	+ 0.1	90	23	77	47	9	58	30		61	58	74	2.29	− 0.3	12	7,230	nw.	37	nw.	25	6	20	5	5.1	.....	.....
Saginaw	641	69	77	29.25	29.93	.....	67.4	.....	88	23	78	48	27	57	30		60	56	72	1.63	− 1.2	9	5,102	nw.	26	sw.	20	10	16	5	4.6	.....	.....
Sault Sainte Marie	614	11	52	29.22	29.90	− .09	63.0	+ 2.4	87	6	72	43	9	55	31		59	57	83	1.09	− 2.0	11	6,031	nw.	38	nw.	25	7	10	14	6.2	.....	.....
Chicago	823	140	310	29.09	29.96	− .04	73.4	+ 2.2	98	4	81	57	28	66	25		63	57	61	1.10	− 1.8	7	8,186	w.	31	s.	20	15	14	2	3.5	.....	.....
Green Bay	617	109	144	29.26	29.92	− .07	67.5	− 1.2	86	14	77	49	27	58	26		60	56	72	1.60	− 1.5	10	7,318	sw.	38	s.	15	12	13	6	5.1	.....	.....
Milwaukee	681	119	133	29.22	29.95	− .05	70.4	+ 3.4	89	14	78	53	27	62	23		62	57	65	1.87	− 1.0	7	6,777	w.	27	ne.	1	19	10	2	3.5	.....	.....
Duluth	1,133	11	47	28.72	29.92	− .05	65.0	+ 0.1	84	19	74	46	27	56	28		59	55	74	2.99	− 0.5	15	8,348	nw.	40	nw.	6	11	13	7	4.9	.....	.....
North Dakota.							68.7	+ 2.0											62	1.80	− 0.5									3.1		
Moorhead	940	8	57	28.95	29.95	− .01	68.2	+ 2.3	93	19	80	42	31	56	36		60	57	74	2.83	− 0.3	8	5,641	nw.	34	nw.	12	23	6	2	2.0	.....	.....
Bismarck	1,674	8	57	28.21	29.96	+ .02	70.6	+ 2.5	95	19	84	45	25	57	45		58	50	56	1.46	− 0.5	6	7,277	nw.	47	nw.	4	19	10	2	3.3	.....	.....
Devils Lake	1,482	11	44	28.37	29.91	− .03	67.0	+ 1.9	96	19	80	42	25	54	36		57	52	65	2.28	− 0.5	10	6,365	nw.	34	nw.	16	15	12	4	3.7	.....	.....
Grand Forks	835	12	89	.....	.....	.....	66.0	.....	95	19	78	38	27	54	35		59	.....	.....	2.98	.....	13	.....	nw.	30	nw.	16	16	7	8	.....	.....	.....
Williston	1,872	41	48	27.97	29.90	− .03	69.0	+ 1.1	94	31	83	41	30	55	40		56	48	54	0.65	− 0.7	5	6,487	se.	40	w.	5	15	16	0	3.4	.....	.....
Ellendale	1,457	10	56	28.42	29.96	.....	67.4	.....	92	5	81	42	25	54	40		59	54	68	0.68	.....	3	9,083	nw.	52	n.	12	13	10	8	4.5	.....	.....
Upper Mississippi Valley.							72.5	− 0.5											69	2.60	− 0.6									3.9		
Minneapolis	918	10	298	28.95	29.92	.....	69.4	.....	89	14	79	51	31	60	28		.....	.....	.....	1.88	− 1.8	10	7,763	nw.	37	n.	6	13	15	3	3.9	.....	.....
St. Paul	837	201	236	29.05	29.94	− .03	68.5	− 1.0	86	14	78	50	31	59	30		.....	.....	.....	2.22	− 1.2	10	8,157	nw.	49	nw.	20	14	15	2	3.7	.....	.....
La Crosse	714	11	48	29.18	29.94	− .04	69.2	− 0.8	88	4	80	45	31	58	32		.....	.....	.....	1.39	− 2.0	10	2,846	sw.	16	nw.	16	18	10	3	3.6	.....	.....
Madison	974	70	78	28.94	29.96	− .03	69.0	− 0.6	88	22	78	51	31	60	24	61	56	69		0.89	− 2.3	7	6,090	nw.	30	sw.	4	14	10	7	4.7	.....	.....
Wausau	1,247	4	.....	28.62	29.93	.....	64.6	.....	84	14	74	44	28	55	32		.....	.....	.....	2.51	.....	9	.....	nw.	.....	.....	.....	17	7	7	3.9	.....	.....
Charles City	1,015	10	49	28.91	29.97	00	69.6	− 1.1	91	3	82	45	31	58	35	62	58	71		1.90	− 1.5	9	3,922	nw.	24	sw.	20	15	16	0	3.5	.....	.....
Davenport	606	71	79	29.32	29.98	00	73.0	0.0	96	4	83	50	31	63	26	64	60	67		3.58	− 0.1	7	4,650	sw.	26	w.	6	19	7	5	3.5	.....	.....
Des Moines	861	84	97	29.08	29.98	+ .01	73.4	+ 0.4	94	3	83	49	31	63	30	64	60	68		2.19	− 1.4	7	4,554	nw.	35	sw.	20	15	12	4	3.8	.....	.....
Dubuque	698	81	96	29.24	29.98	00	70.8	− 1.2	95	4	80	50	31	61	28	63	58	70		1.58	− 1.5	7	3,877	nw.	24	n.	16	14	13	4	4.2	.....	.....
Keokuk	614	64	78	29.33	29.99	+ .01	74.3	− 0.3	97	4	84	53	31	64	28	65	60	65		3.85	+ 0.6	10	4,659	s.	22	nw.	30	15	15	1	3.8	.....	.....
Cairo	356	87	93	29.61	29.98	− .01	77.2	+ 0.2	98	6	86	61	28	68	26	68	65	74		3.41	+ 0.5	7	4,943	s.	57	n.	13	8	14	9	5.5	.....	.....
Peoria	609	11	45	29.33	29.99	00	71.9	− 0.6	96	4	33	49	31	61	27	64	61	75		4.73	+ 1.8	9	3,586	s.	30	nw.	24	19	6	6	3.2	.....	.....
Springfield, Ill	644	10	91	29.30	29.96	− .03	74.0	0.0	98	4	85	52	31	63	29	65	61	69		1.85	− 1.0	10	5,377	w.	27	w.	15	12	13	6	4.3	.....	.....
Hannibal	534	74	109	29.41	29.98	00	74.1	− 0.9	99	6	84	54	26	64	31		.....	.....	.....	3.83	+ 0.4	13	5,280	sw.	34	ne.	6	15	10	6	4.1	.....	.....
St. Louis	567	265	303	29.38	29.98	− .01	77.1	− 0.1	102	6	86	58	31	68	29	66	60	61		3.03	+ 0.4	7	8,054	nw.	50	sw.	20	18	9	4	3.1	.....	.....
Missouri Valley.							74.8	− 1.0											65	3.09	− 0.3									4.0		
Columbia, Mo	781	11	84	29.16	29.97	00	74.7	0.0	102	6	85	53	26	64	33		.....	.....	.....	5.37	+ 2.3	11	4,564	ne.	35	nw.	15	17	10	4	3.4	.....	.....
Kansas City	963	161	181	28.96	29.96	− .01	76.6	+ 0.8	100	6	86	57	31	68	27	66	61	64		8.14	+ 3.4	9	7,071	s.	40	n.	15	14	11	6	4.0	.....	.....
St. Joseph	967	11	49	28.95	29.96	.....	75.4	.....	100	6	85	52	31	65	28	66	62	69		2.68	.....	6	4,721	se.	50	w.	7	13	11	7	4.3	.....	.....
Springfield, Mo	1,324	98	104	28.62	30.00	+ .03	77.2	+ 2.4	97	6	87	57	31	68	26	67	62	67		0.53	− 3.8	6	6,542	s.	33	n.	25	20	8	3	2.8	.....	.....
Iola	984	11	50	28.98	29.96	.00	78.4	+ 2.1	100	6	90	53	31	66	36	.....	.....	.....	.....	2.22	− 1.2	9	4,255	s.	33	n.	25	12	14	5	4.6	.....	.....
Topeka	983	92	107	.....	.....	.....	78.6	+ 2.6	101	6	88	52	25	66	33	.....	.....	.....	.....	3.06	− 1.2	8	6,969	sw.	56	se.	26	10	18	3	4.0	.....	.....
Drexel	1,209	10	54	28.58	29.94	.....	72.6	.....	101	3	84	50	31	61	32	64	61	72		3.63	.....	10	6,306	se.	47	sw.	12	18	7	6	3.6	.....	.....
Lincoln	1,189	11	84	28.72	29.96	+ .01	74.8	+ 0.3	102	3	86	50	31	64	31	65	60	66		4.67	+ 1.0	8	6,280	se.	70	nw.	4	11	10	10	5.0	.....	.....
Omaha	1,105	115	122	28.81	29.97	+ .01	75.0	+ 0.6	101	3	85	53	31	66	30	65	60	65		2.91	− 0.7	10	4,905	s.	35	s.	12	12	14	5	4.4	.....	.....
Valentine	2,598	47	54	27.30	29.97	+ .03	71.8	+ 0.5	101	11	86	46	30	58	41	59	52	57		1.60	− 1.2	6	6,852	s.	56	w.	3	13	15	3	3.8	.....	.....
Sioux City	1,135	94	164	28.78	29.96	+ .01	72.6	0.0	99	3	83	45	31	62	33	63	58	67		1.91	− 1.1	6	6,313	s.	38	w.	3	13	14	4	4.2	.....	.....
Huron	1,306	59	74	28.60	29.97	+ .02	70.3	+ 1.2	94	13	83	42	31	58	34	61	56	68		1.31	− 1.3	5	6,887	se.	43	nw.	12	19	9	3	3.2	.....	.....
Pierre	1,572	70	75	28.30	29.94	.00	75.1	+ 2.0	103	5	88	50	30	62	40	61	53	55		2.24	+ 0.2	5	6,802	e.	35	n.	12	15	7	9	4.2	.....	.....
Yankton	1,233	49	57	28.66	29.95	.00	72.3	− 0.5	98	3	84	48	31	61	34	.....	.....	.....	.....	3.12	0.0	6	4,791	w.	35	w.	3	12	14	5	4.3	.....	.....

TABLE I.—*Climatological data for Weather Bureau Stations, August, 1919*—Continued.

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.													Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity.	Precipitation.			Wind.						Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow on ground at end of month.
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max.+mean min.÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.							Total.	Departure from normal.	Days with 0.01 inch or more.	Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Maximum velocity. Direction.	Maximum velocity. Date.						
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	°F.	°F.	°F		°F	°F		°F	°F	°F	°F	%	*In.*	*In.*		*Miles*									*0–10*	*In.*	*In.*
Northern Slope.							**69.2**	**+ 2.5**										**48**	**0.51**	**— 0.8**											**3.7**		
Billings	3,140	5					69.3		96	31	88	38	30	51	51				0.58		4		sw.					14	16	1			
Havre	2,505	11	44	27.33	29.91	.00	70.4	+ 3.5	97	17	85	47	30	56	42	56	47	52	0.76	— 0.5	3	4,430	e.	36	sw.	3	17	12	2	3.2		
Helena	4,110	87	114	25.83	29.93	— .01	69.7	+ 3.6	93	18	83	49	15	56	37	52	38	37	0.12	— 0.6	3	6,000	sw.	39	se.	31	12	12	7	4.3		
Kalispell	2,962	11	34	26.92	29.92	— .01	65.0	+ 2.1	93	18	80	43	14	50	39	51	41	50	1.06	+ 0.2	8	4,124	nw.	35	se.	1	20	7	4	3.5		
Miles City	2,371	26	48	27.45	29.94	+ .01	75.0	+ 3.5	101	31	88	46	30	62	44	61	54	55	0.38	— 0.6	2	4,507	se.	24	n.	11	16	15	0	2.9		
Rapid City	3,259	50	58	26.64	29.97	+ .04	71.8	+ 3.0	97	5	86	48	30	58	45	56	44	42	0.35	— 1.8	2	6,323	w.	36	nw.	12	20	19	1	2.9		
Cheyenne	6,088	84	101	24.13	29.96	+ .04	68.0	+ 2.2	89	22	81	45	30	55	39	53	43	48	0.43	— 1.0	6	7,781	s.	36	nw.	19	15	11	5	4.0		
Lander	5,372	60	68	24.74	29.96	+ .04	68.6	+ 2.9	93	22	85	41	21	52	49	50	36	38	0.31	— 0.2	4	3,827	sw.	44	nw.	18	15	10	6	4.2		
Sheridan	3,790	10	47	26.13	29.96		68.2		98	31	87	35	30	50	56	54	44	51	0.18		3	3,644	nw.	38	sw.	11	14	13	4	3.6		
Yellowstone Park	6,200	11	48	24.01	30.01	+ .08	61.4	+ 0.5	88	24	77	37	29	46	44	47	36	47	0.40	— 0.6	7	5,174	s.	38	s.	31	11	14	6	4.6		
North Platte	2,821	11	51	27.12	30.09	+ .06	73.0	+ 0.8	97	23	87	48	31	59	44	61	56	64	0.76	— 1.7	5	4,307	se.	25	n.	6	20	6	5	3.5		
Middle Slope.							**77.7**	**+ 2.4**										**58**	**1.72**	**— 0.7**											**3.9**		
Denver	5,292	106	113	24.84	29.98	+ .06	72.6	+ 2.2	93	23	85	54	16	60	36	56	46	48	1.00	— 0.3	5	4,941	s.	35	se.	2	15	11	5	4.0		
Pueblo	4,685	80	86	25.36	29.94	+ .03	74.6	+ 2.5	98	23	89	53	26	60	41	59	51	53	3.23	+ 1.7	6	4,745	nw.	30	nw.	2	13	16	2	4.1		
Concordia	1,392	50	58	28.52	29.96	+ .01	77.0	+ 0.5	101	6	89	52	31	65	35	65	59	60	1.00	— 1.8	5	5,466	s.	30	se.	12	13	11	7	4.5		
Dodge City	2,509	11	51	27.40	29.94	+ .01	79.4	+ 2.9	104	14	93	55	16	66	36	65	59	60	1.23	— 1.4	2	6,195	s.	28	ne.	14	22	8	1	2.9		
Wichita	1,358	139	158	28.55	29.94	— .01	80.4	+ 2.9	102	5	92	58	29	69	33	68	62	61	1.61	— 1.5	6	8,380	s.	67	n.	29	15	14	2	3.5		
Altus	1,410	5					82.8		104	13	76	67	10	70	32				1.48		5							16	6	9			
Muskogee	652	4					82.5		105	6	94	60	19	71	38				5.01		5		se.					19	7	5			
Oklahoma	1,214	10	47	28.71	29.95	+ .91	82.0	+ 3.5	101	6	94	60	31	70	32	70	66	66	2.28	— 0.9	7	8,099	s.	39	e.	29	14	10	7	4.4		
Southern Slope							**80.3**	**+ 1.0**										**61**	**1.96**	**— 0.2**											**3.4**		
Abilene	1,738	10	52	28.19	29.95	+ .03	81.9	+ 0.7	101	17	93	63	26	71	30	70	65	65	2.33	+ 0.4	5	6,306	s.	24	n.	9	16	7	8	4.2		
Amarillo	3,676	10	49	26.32	29.97	+ .05	77.6	+ 3.0	101	6	91	60	8	64	35	65	60	65	3.21	+ 0.4	7	6,760	s.	38	sw.	5	15	16	0	3.8		
Del Rio	944	64	71	28.97	29.94	+ .04	82.7	— 1.3	98	18	92	70	23	74	23				1.58	— 1.0	4	6,864	se.	32	n.	20	20	8	3	3.0		
Roswell	3,566	75	85	26.39	29.91	+ .03	77.9	+ 1.4	98	11	92	58	22	64	35	63	56	53	0.72	— 0.7	4	4,451	s.	35	w.	5	19	11	1	2.7		
Southern Plateau.							**78.4**	**+ 1.1**										**46**	**1.21**	**— 0.1**											**2.5**		
El Paso	3,762	110	132	26.20	29.86	+ .02	81.0	+ 2.4	100	13	93	64	21	69	30	64	55	50	0.72	— 1.0	8	6,223	se.	42	ne.	20	20	11	0	3.1		
Santa Fe	7,013	57	66	23.38	29.90	+ .02	69.0	+ 2.0	85	11	80	53	20	58	27	54	47	54	2.06	— 0.3	6	4,578	e.	29	se.	16	7	24	0	4.4		
Flagstaff	6,908	8	57	23.49	29.92	+ .08	63.8	+ 1.0	86	22	78	43	5	49	40	53			2.87		6		nw.	24	n.	19	20	10	1			
Phoenix	1,108	11	81	28.70	29.81	+ .02	88.6	— 0.4	110	13	101	79	5	76	34	71	64	49	2.40	+ 1.4	5	3,532	w.	49	e.	23	26	3	2	1.9		
Yuma	141	9	54	29.64	29.78	+ .02	90.0	— 0.1	116	13	105	68	5	75	41	73	65	53	0.88	+ 0.5	4	3,771	sw.	36	se.	30	25	4	2	1.6		
Independence	3,910	11	42	25.97	29.92	+ .11	77.9	+ 1.5	101	20	94	52	4	62	39	54	33	23	0.00	— 0.1	0	4,251	se.	25	se.	8	24	7	0	1.7		
Middle Plateau.							**73.7**	**+ 0.2**										**32**	**0.34**	**— 0.5**											**2.4**		
Reno	4,532	74	81	25.50	29.90	+ .06	71.3	+ 4.3	99	20	89	44	12	54	46	51	36	35	0.08	— 0.2	2	5,193	w.	32	w.	4	26	5	0	1.4		
Tonopah	6,090	12	20	24.14	29.91		74.4		92	22	86	55	3	63	27	50	28	21	0.01	— 0.4	1	5,855	se.	29	e.	16	21	10	0	2.0		
Winnemucca	4,344	18	56	25.64	29.95	+ .07	71.2	+ 0.4	97	20	91	42	1	52	51	50	32	28	T.	— 0.2	0	4,363	sw.	23	sw.	17	28	3	0	1.3		
Modena	5,479	10	43	24.69	29.91	+ .05	71.3	+ 2.7	96	23	88	46	4	54	46	51	35	34	0.50	— 1.3	6	8,905	sw.	40	s.	25	18	10	3	3.1		
Salt Lake City	4,360	163	203	25.65	29.92	+ .01	77.4	+ 1.9	100	24	89	59	9	66	35	57	42	34	0.50	— 0.3	6	5,648	s.	42	se.	17	16	7	8	3.9		
Grand Junction	4,602	82	96	25.44	29.95	+ .05	77.4	+ 1.5	99	23	92	59	20	63	35	57	43	37	0.63	— 0.4	7	4,378	se.	29	ne.	19	19	9	3	2.8		
Northern Plateau.							**72.5**	**+ 2.6**										**35**	**0.42**	**— 0.3**											**2.8**		
Baker	3,471	48	53	26.46	29.98	+ .03	67.8	+ 2.9	97	25	85	39	4	50	43	52	39	41	0.46	+ 0.1	4	4,270	se.	28	sw.	11	17	10	4	3.2		
Boise	2,739	78	86	27.13	29.92	— .01	74.4	+ 2.6	98	24	90	49	4	50	41	55	38	31	T.	— 0.2	0	3,277	nw.	27	w.	3	24	5	2	2.0		
Lewiston	757	40	48	29.14	29.93	— .02	74.4	+ 3.9	101	18	91	50	29	58	42				0.12	— 0.2	2	2,440	e.	25	nw.	31	15	8	8	2.0		
Pocatello	4,477	60	68	25.51	29.92	.00	73.3	+ 2.8	99	24	88	51	10	59	41	52	33	29	0.44	— 0.1	5	6,644	se.	38	se.	8	12	14	5	4.3		
Spokane	1,929	101	110	27.94	29.94	— .01	69.8	+ 1.9	95	18	84	47	28	56	40	54	42	43	1.02	+ 0.5	4	4,152	sw.	28	w.	31	16	10	5	3.5		
Walla Walla	991	57	65	28.89	29.94	— .02	75.6	+ 1.8	100	17	89	53	28	62	38	57	41	33	0.06	— 0.4	1	3,428	s.	19	w.	30	27	3	1	2.0		
North Pacific Coast Region.							**62.3**	**+ 0.4**										**74**	**0.12**	**— 0.7**											**4.7**		
North Head	211	11	56	29.85	30.07	+ .04	55.6	— 2.3	71	15	59	50	10	52	17	54	53	94	0.26	— 0.3	8	9,768	nw.	38	s.	30	3	12	16	7.5		
North Yakima	1,071	4					71.4		98	18	89	47	29	54	42				0.08		1												
Port Angeles	20	8	48	30.06	30.10		57.0		79	10	66	41	22	48	35				T.	— 0.6	0	4,313	nw.	20	nw.	11	19	7	5	3.2		
Seattle	125	215	250	29.93	30.06	+ .06	63.0	— 0.1	86	16	72	49	9	54	28	53	52	71	0.08	— 0.6	3	4,902	n.	27	s.	31	12	12	7	4.5		
Tacoma	213	113	120	29.83	30.05	+ .03	63.1	+ 0.1	90	16	73	47	28	53	34	57	52	70	0.02	— 0.7	1	3,829	n.	24	w.	31	5	16	10	5.8		
Tatoosh Island	86	7	57	29.97	30.07	+ .07	54.0	— 1.3	66	24	58	48	10	50	18	53	52	94	0.35	— 1.8	12	8,019	s.	42	s.	11	7	5	19	6.5		
Medford	1,425	4					71.7		102	16	92	45	5	52	49				0.03		1												
Portland, Oreg.	153	68	106	29.86	30.02	+ .01	68.3	+ 2.7	98	15	80	50	8	57	33	59	52	61	0.10	— 0.6	2	4,189	nw.	21	e.	15	21	4	6	3.1		
Roseburg	510	9	57	29.46	30.00	.00	69.6	+ 3.4	100	15	86	47	5	54	45	57	49	56	0.02	— 0.3	1	2,555	n.	17	n.	14	20	9	2	2.5		
Middle Pacific Coast Region.							**65.0**	**+ 0.1**										**59**	**0.00**	**0.0**											**3.7**		
Eureka	62	73	89	29.98	30.06	+ .06	55.9	+ 0.1	68	31	60	48	25	52	17	53	51	88	0.01	— 0.1	1	3,998	nw.	20	n.	31	3	14	14	7.0		
Mount Tamalpais	2,375	11	18	27.54	29.97	+ .04	68.4	+ 2.5	90	14	76	44	11	60	29	53	38	36	T.	0.0	0	11,826	nw.	78	nw.	27	27	4	0	1.1		
Point Reyes Light	490	7	18	29.45	29.97	+ .11	53.8	— 0.7	67	28	58	45	28	50	22				0.00	0.0	0	14,404	nw.	58	nw.	27	4	4	23	8.3		
Red Bluff	332	50	56	29.53	29.87	+ .01	79.6	— 1.4	108	19	96	53	11	63	42	60	44	34	0.00	0.0	0	2,399	se.	17	s.	26	31	0	0	0.7		
Sacramento	69	106	117	29.83	29.90	+ .05	72.8	+ 0.7	107	19	89	50	7	56	45	59	50	53	T.	0.0	0	6,643	s.	23	s.	10	28	3	0	0.8		
San Francisco	155	208	243	29.82	29.90	+ .07	58.4	+ 0.4	78	27	64	53	10	52	23	54	52	84	T.	0.0	0	9,157	sw.	38	sw.	1	6	16	9	5.8		
San Jose	141	12	110	29.84	29.99		65.8	— 0.9	92	14	79	44	12	52	43				0.01	0.0	1	4,239	nw.	19	nw.	31	26	5	0	2.3		
South Pacific Coast Region.							**71.2**	**— 0.1**										**66**	**0.00**	**0.0**											**2.4**		
Fresno	327	89	98	29.54	29.88	+ .06	81.2	.00	108	21	98	54	11	64	49	60	43	32	0.00	0.0	0	5,858	nw.	25	nw.	31	30	1	0	0.5		
Los Angeles	338	159	191	29.59	29.94	+ .06	70.2	— 1.3	89	12	80	55	15	60	29	62	59	76	T.	0.0	0	3,857	sw.	16	s.	5	22	9	0	2.6		
San Diego	87	62	73	29.85	29.94	+ .05	68.4	— 0.3	78	26	73	60	12	64	15	64	62	84	0.01	0.0	1	4,426	nw.	20	nw.	30	17	11	3	3.9		
San Luis Obispo	201	32	40	29.77	29.98	+ .04	64.8	+ 1.3	91	24	77	48	1	52	41	56	52	74	0.00	0.0	0	2,742	nw.	14	nw.	7	27	4	0	2.4		
West Indies.																																			
San Juan, P. R	82	8	54	29.95	30.04	+ .07	80.5		86	26	85	72	29	76	13				1.53	— 5.9	16	11,660	e.	38	e.	19	15	16	0	4.1		
Panama Canal.																																			
Balboa Heights	118	7	97	29.73	29.85	+ .01	81.4	+ 1.2	92	4	88	72	20	75	18	76	75	85	5.82	— 1.9	22	4,884	nw.	32	sw.	5	0	21	10	7.0		
Colon	36	15	97	29.82	29.86	.00	80.1	+ 1.0	87	24	85	73	21	76	13	77	76	85	6.77	— 8.1	22	6,823	w.	28	s.	21	0	10	21	8.2		

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes, for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during August, 1919, at all stations furnished with self-registering gages.*

Stations.	Date.	Total duration.		Total amount of precipitation.	Excessive rate.		Amount before excessive rate began.	Depths of precipitation (in inches) during periods of time indicated.													
		From—	To—		Began—	Ended—		5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Abilene, Tex.	20			2.02														0.65			
Albany, N. Y.	19	5:37 p. m.	6:04 p. m.	0.62	5:41 p. m.	5:56 p. m.	0.01	0.32	0.47	0.60											
Alpena, Mich.	23	7:25 a. m.	9:25 a. m.	0.98	7:28 a. m.	7:53 a. m.	0.01	0.09	0.18	0.42	0.66	0.75									
Amarillo, Tex.	9	D. N. a. m.	5:20 a. m.	0.91	2:24 a. m.	2:50 a. m.	0.09	0.09	0.23	0.30	0.41	0.55	0.58								
Anniston, Ala.	23	3:28 p. m.	10:00 p. m.	1.88	3:52 p. m.	4:36 p. m.	0.02	0.08	0.24	0.32	0.42	0.60	0.83	1.14	1.29	1.35					
Asheville, N. C.	11–12			0.81														0.53			
Atlanta, Ga.	18	4:35 p. m.	5:30 p. m.	0.68	5:07 p. m.	5:22 p. m.	0.16	0.18	0.34	0.51											
Atlantic City, N. J.	13–14	5:30 a. m.	7:30 a. m.	8.70	2:52 p. m.	3:42 p. m.	1.92	0.05	0.10	0.15	0.22	0.26	0.32	0.40	0.47	0.54	0.61				
					3:42 p. m.	4:32 p. m.		0.70	0.83	0.98	1.11	1.24	1.37	1.53	1.65	1.72	1.78				
					4:32 p. m.	5:22 p. m.		1.81	1.87	1.92	1.98	2.05	2.08	2.12	2.19	2.26	2.33				
					5:22 p. m.	6:12 p. m.		2.42	2.51	2.56	2.65	2.78	2.91	3.05	3.17	3.34	3.49				
					6:12 p. m.	7:02 p. m.		3.66	3.90	4.06	4.21	4.41	4.59	4.70	4.76	4.83	4.90				
					7:02 p. m.	7:52 p. m.		4.96	4.99	5.02	5.05	5.13	5.19	5.22	5.23	5.25	5.28				
					7:52 p. m.	8:12 p. m.		5.30	5.38	5.56	5.65										
Augusta, Ga.	6			0.44														0.44			
Baker, Oreg.	3			0.39														0.38			
Baltimore, Md.	6	2:15 p. m.	5:38 p. m.	1.36	4:12 p. m.	4:39 p. m.	0.04	0.16	0.58	1.04	1.20	1.27	1.30								
	21	5:32 p. m.	7:45 p. m.	0.84	6:23 p. m.	6:38 p. m.	0.01	0.26	0.67	0.81											
Bentonville, Ark.	15–16	10:40 p. m.	5:15 a. m.	1.64	3:22 a. m.	3:40 a. m.	0.76	0.20	0.39	0.66	0.79										
Binghamton, N. Y.	21	7:55 p. m.	9:50 p. m.	0.77	9:15 p. m.	9:33 p. m.	0.19	0.10	0.24	0.45	0.56										
Birmingham, Ala.	23	12:48 p. m.	5:15 p. m.	0.90	2:12 p. m.	2:34 p. m.	0.01	0.15	0.41	0.62	0.72	0.75									
Bismarck, N. Dak.	4	7:20 a. m.	8:15 a. m.	0.89	7:23 a. m.	7:43 a. m.	0.01	0.23	0.53	0.69	0.79										
Block Island, R. I.	13–14			1.42														0.42			
Boise, Idaho.	8			T.														T.			
Boston, Mass.	14			1.85														0.53			
Buffalo, N. Y.	30			0.60														0.54			
Burlington, Vt.	24	6:40 a. m.	11:20 a. m.	1.04	7:52 a. m.	8:17 a. m.	0.01	0.29	0.44	0.50	0.55	0.60									
Cairo, Ill.	13	6:14 p. m.	7:38 p. m.	1.02	6:22 p. m.	6:53 p. m.	0.01	0.09	0.40	0.71	0.84	0.90	0.98	1.00							
	15–16	11:37 p. m.	D. N. a. m.	1.08	12:08 a. m.	12:28 a. m.	0.01	0.19	0.38	0.51	0.57										
Canton, N. Y.	21			0.50														0.42			
Charles City, Iowa.	12			1.01														0.60			
Charleston, S. C.	6	11:58 a. m.	1:50 p. m.	1.52	12:06 p. m.	1:23 p. m.	0.01	0.08	0.14	0.14	0.25	0.30	0.31	0.31	0.35	0.42	0.44	0.88	1.49		
	10	1:50 p. m.	3:50 p. m.	1.04	2:17 p. m.	2:49 p. m.	0.04	0.18	0.36	0.50	0.65	0.72	0.82	0.87							
Charlotte, N. C.	16	5:52 p. m.	8:05 p. m.	1.07	6:03 p. m.	6:12 p. m.	0.01	0.43	0.75												
Chattanooga, Tenn.	10			0.56														0.56			
Cheyenne, Wyo.	9			0.16														0.16			
Chicago, Ill.	17			0.43														0.36			
Cincinnati, Ohio.	5			0.20														0.16			
Cleveland, Ohio.	4	8:24 p. m.	10:20 p. m.	1.23	8:54 p. m.	9:24 p. m.	0.03	0.08	0.29	0.54	0.69	0.83	0.96								
	5	2:23 p. m.	3:09 p. m.	0.59	2:33 p. m.	2:59 p. m.	0.01	0.20	0.28	0.41	0.44	0.54	0.57								
	5	3:59 p. m.	8:36 p. m.	2.20	4:18 p. m.	4:47 p. m.	0.01	0.12	0.37	0.81	1.15	1.64	1.80								
Columbia, Mo.	7	12:16 a. m.	7:18 a. m.	1.31	4:46 a. m.	5:03 a. m.	0.47	0.15	0.38	0.52	0.55										
	15–16	6:23 p. m.	D. N. a. m.	1.09	7:13 p. m.	7:38 p. m.	0.02	0.05	0.21	0.48	0.73	0.81									
Columbia, S. C.	8	5:20 p. m.	7:35 p. m.	0.82	5:28 p. m.	5:53 p. m.	0.01	0.07	0.15	0.35	0.43	0.51									
Columbus, Ohio.	4–5	9:10 p. m.	D. N. a. m.	1.34	9:19 p. m.	9:40 p. m.	0.02	0.13	0.52	0.92	1.25	1.30									
Concord, N. H.	24			0.35														0.20			
Concordia, Kans.	12	3:12 p. m.	3:50 p. m.	0.58	3:21 p. m.	3:46 p. m.	0.03	0.07	0.17	0.25	0.45	0.55									
Corpus Christi, Tex.	12			0.09														0.09			
Dallas, Tex.	22	8:19 a. m.	12:36 p. m.	1.60	11:51 a. m.	12:28 p. m.	0.44	0.16	0.26	0.38	0.64	0.83	0.90	1.11	1.16						
Davenport, Iowa.	6	12:15 p. m.	2:00 p. m.	1.21	12:19 p. m.	12:53 p. m.	0.03	0.13	0.32	0.68	0.92	1.01	1.08	1.13							
	20	9:00 p. m.	10:30 p. m.	1.09	9:05 p. m.	9:22 p. m.	0.03	0.35	0.74	0.97	1.04										
Dayton, Ohio.	16	10:10 a. m.	12:14 p. m.	0.65	10:19 a. m.	10:28 a. m.	0.01	0.42	0.52												
	21	D. N. a. m.	6:20 a. m.	1.00	5:02 a. m.	5:22 a. m.	0.44	0.14	0.28	0.42	0.55										
Del Rio, Tex.	21	9:25 a. m.	12:30 p. m.	1.00	10:07 a. m.	10:32 a. m.	0.26	0.13	0.26	0.44	0.56	0.63									
Denver, Colo.	27			0.46														0.42			
Des Moines, Iowa.	3			0.70														0.56			
Detroit, Mich.	4	5:30 p. m.	7:35 p. m.	0.69	7:00 p. m.	7:15 p. m.	0.01	0.23	0.49	0.64											
Devils Lake, N. Dak.	2	8:17 p. m.	D. N. p. m.	0.93	8:22 p. m.	8:47 p. m.	0.01	0.31	0.55	0.61	0.69	0.80									
Dodge City, Kans.	19	5:25 p. m.	D. N. p. m.	1.02	5:40 p. m.	6:20 p. m.	0.04	0.14	0.31	0.42	0.49	0.51	0.54	0.63	0.71						
Drexel, Nebr.	10–11			1.06														(*)			
Dubuque, Iowa.	13			0.83														0.28			
Duluth, Minn.	28			0.36														0.26			
Eastport, Me.	22			0.46														0.31			
Elkins, W. Va.	18			0.55														0.35			
Ellendale, N. Dak.	28			0.29														0.29			
El Paso, Tex.	19			0.31														0.19			
Erie, Pa.	18	10:07 a. m.	10:54 a. m.	0.75	10:11 a. m.	10:31 a. m.	0.01	0.24	0.35	0.65	0.74										
	30	D. N. a. m.	6:10 a. m.	0.79	4:22 a. m.	4:52 a. m.	0.12	0.13	0.23	0.26	0.38	0.46	0.51								
Escanaba, Mich.	17			0.48														0.32			
Eureka, Calif.	3			0.01														T.			
Evansville, Ind.	1	10:28 a. m.	11:52 a. m.	1.41	10:32 a. m.	10:56 a. m.	0.01	0.33	0.47	0.93	1.32	1.38									
Flagstaff, Ariz.	1			1.34														(*)			
Fort Smith, Ark.	16	5:04 a. m.	7:33 a. m.	1.37	5:14 a. m.	5:31 a. m.	0.01	0.19	0.48	0.64	0.68										
	17–18	10:17 p. m.	D. N. a. m.	1.42	11:58 p. m.	12:38 a. m.	0.29	0.15	0.45	0.56	0.61	0.70	0.81	0.85	0.95						
	20	11:43 a. m.	2:12 p. m.	0.80	12:03 p. m.	12:17 p. m.	0.01	0.17	0.47	0.60											
Fort Wayne, Ind.	16			0.58														0.32			
Fort Worth, Tex.	10			0.76														0.73			
Fresno, Calif.	(‡)			(‡)														(‡)			
Galveston, Tex.	21	D. N. a. m.	D. N. a. m.	0.66	2:42 a. m.	2:50 a. m.	0.01	0.46	0.63												
Grand Haven, Mich.	4			0.61														0.22			
Grand Junction, Colo.	1			0.18														0.14			
Grand Rapids, Mich.	4	8:55 p. m.	D. N. p. m.	0.72	10:33 p. m.	10:58 p. m.	0.02	0.17	0.32	0.46	0.60	0.67									
Green Bay, Wis.	4			0.52														0.31			
Greenville, S. C.	1	3:53 p. m.	5:55 p. m.	0.86	3:59 p. m.	4:14 p. m.	0.01	0.14	0.45	0.74											
	29–30	4:00 p. m.	D. N. a. m.	1.44	5:35 p. m.	6:15 p. m.	0.17	0.11	0.17	0.21	0.30	0.69	0.75	0.86	0.96						
Hannibal, Mo.	6–7	D. N. p. m.	D. N. a. m.	0.79	11:27 p. m.	12:06 a. m.	0.01	0.07	0.11	0.18	0.23	0.35	0.42	0.55	0.60						
	29	D. N. a. m.	5:15 a. m.	0.73	3:20 a. m.	3:36 a. m.	0.05	0.10	0.31	0.53	0.59										
Harrisburg, Pa.	18	4:45 p. m.	7:00 p. m.	1.12	5:01 p. m.	5:22 p. m.	0.02	0.38	0.68	0.82	0.95	0.97									
Hartford, Conn.	31			0.46														0.45			
Hatteras, N. C.	13			0.28														0.23			
Havre, Mont.	1			0.30														0.15			
Helena, Mont.	1			0.08														0.04			
Houghton, Mich.	13	3:00 p. m.	3:30 p. m.	0.55	3:06 p. m.	3:23 p. m.	0.03	0.10	0.31	0.48	0.52										
Houston, Tex.	23	10:35 a. m.	11:21 a. m.	0.74	10:46 a. m.	11:04 a. m.	0.01	0.22	0.51	0.68	0.73										
Huron, S. Dak.	12			1.03														0.80			
Independence, Cal.	(‡)			(‡)														(‡)			
Indianapolis, Ind.	24	2:51 p. m.	4:52 p. m.	1.29	3:08 p. m.	4:04 p. m.	0.01	0.10	0.29	0.29	0.29	0.29	0.33	0.35	0.55	0.79	1.00	1.25			
Iola, Kans.	28			0.53														0.44			

* Self-register not in use.

‡ No precipitation occurred during month.

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes, for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during August, 1919, at all stations furnished with self-registering gages.*

Stations.	Date.	Total duration.		Total amount of precipitation.	Excessive rate.		Amount before excessive rate began.	Depths of precipitation (in inches) during periods of time indicated.													
		From—	To—		Began—	Ended—		5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Jacksonville, Fla	3	D. N. a. m.	D. N. a. m.	0.54	2:01 a. m.	2:23 a. m.	0.01	0.19	0.31	0.38	0.48	0.51									
	12	2:29 p. m.	10:40 p. m.	1.01	3:18 p. m.	3:33 p. m.	0.09	0.38	0.60	0.71											
	14	12:40 p. m.	4:50 p. m.	1.07	1:44 p. m.	1:53 p. m.	0.34	0.36	0.61												
	17	12:12 p. m.	12:29 p. m.	0.77	12:15 p. m.	12:27 p. m.	0.01	0.42	0.72	0.76											
Kalispell, Mont	2			0.46														0.46			
Kansas City, Mo	27–28	8:45 p. m.	D. N. a. m.	2.39	10:11 p. m.	11:37 p. m.	0.32	0.10	0.13	0.18	0.35	0.55	0.65	0.68	0.69	0.71	0.74	0.90	1.10	1.27	
	28	8:20 a. m.	12:25 p. m.	2.50	9:06 a. m.	9:56 a. m.	0.20	0.05	0.11	0.22	0.30	0.31	0.33	0.51	0.60	0.70	0.81				
					9:56 a. m.	10:46 a. m.	.....	0.94	0.97	1.00	1.06	1.17	1.31	1.42	1.47	1.55	1.69				
					10:46 a. m.	11:25 a. m.	.....	1.76	1.82	1.85	1.86	1.87	1.96	2.16	2.23						
Keokuk, Iowa	6	8:55 p. m.	12 mid.	1.52	9:07 p. m.	10:07 p. m.	0.03	0.06	0.11	0.19	0.36	0.45	0.54	0.68	0.85	1.04	1.24	1.36			
	12	9:25 a. m.	10:05 a. m.	1.06	9:29 a. m.	9:59 a. m.	0.02	0.30	0.59	0.74	0.75	0.87	1.01								
Key West, Fla	10			0.86														0.36			
Knoxville, Tenn	1	11:02 a. m.	12:20 p. m.	0.93	11:04 a. m.	11:18 a. m.	0.01	0.37	0.77	0.85											
	11	6:22 p. m.	7:45 p. m.	1.72	6:25 p. m.	7:11 p. m.	0.01	0.18	0.66	1.15	1.39	1.45	1.46	1.48	1.53	1.65	1.70				
La Crosse, Wis	15			0.49														0.49			
Lander, Wyo	1			0.25														0.25			
Lansing, Mich	4–5	6:19 p. m.	D. N. a. m.	1.75	8:00 p. m.	8:27 p. m.	0.82	0.11	0.20	0.36	0.40	0.53	0.62								
Lewiston, Idaho	3			0.11														0.06			
Lexington, Ky	21			0.40														0.35			
Lincoln, Nebr	4	7:07 p. m.	8:25 p. m.	0.94	7:33 p. m.	8:00 p. m.	0.01	0.18	0.45	0.64	0.75	0.83	0.87								
	12	5:44 a. m.	8:12 a. m.	1.64	6:09 a. m.	6:56 a. m.	0.03	0.16	0.26	0.37	0.49	0.63	0.91	1.22	1.38	1.46	1.50				
Little Rock, Ark	25	7:30 p. m.	8:10 p. m.	0.83	7:36 p. m.	7:55 p. m.	0.01	0.16	0.41	0.68	0.80										
Los Angeles, Cal	16			T.														T.			
Louisville, Ky	13	8:04 p. m.	10:25 p. m.	1.13	8:58 p. m.	9:24 p. m.	0.15	0.21	0.42	0.60	0.68	0.74	0.78								
Ludington, Mich	29			0.22														0.22			
Lynchburg, Va	5			1.26														0.61			
Macon, Ga	11	5:21 p. m.	9:15 p. m.	1.58	5:32 p. m.	6:22 p. m.	0.01	0.15	0.47	0.74	0.83	0.90	1.02	1.12	1.23	1.33	1.39				
	31	5:56 p. m.	7:20 p. m.	0.89	6:13 p. m.	6:44 p. m.	0.11	0.13	0.28	0.33	0.43	0.58	0.68	0.72							
Madison, Wis	17			0.34														0.23			
Marquette, Mich	29			0.64														0.41			
Memphis, Tenn	15			0.21														0.15			
Meridian, Miss	3	3:28 p. m.	D. N. p. m.	1.92	3:30 p. m.	4:05 p. m.	0.01	0.29	0.59	0.98	1.26	1.42	1.53	1.59							
	14	7:15 p. m.	D. N. p. m.	1.05	7:22 p. m.	7:45 p. m.	0.01	0.22	0.50	0.70	0.85	0.92									
	18	3:20 p. m.	4:40 p. m.	3.08	3:22 p. m.	4:32 p. m.	0.01	0.15	0.47	0.73	1.33	1.62	1.79	1.81	2.04	2.36	2.52	2.71	3.07		
Miami, Fla	8	3:28 p. m.	4:58 p. m.	1.09	3:50 p. m.	4:13 p. m.	0.13	0.15	0.19	0.34	0.59	0.66									
	10–11	D. N. p. m.	6:15 a. m.	1.10	1:56 a. m.	2:17 a. m.	0.35	0.30	0.48	0.52	0.58	0.63									
Milwaukee, Wis	4	8:50 p. m.	D. N. p. m.	0.88	8:56 p. m.	9:17 p. m.	0.01	0.24	0.52	0.71	0.78	0.83									
Minneapolis, Minn	6	8:50 a. m.	9:55 a. m.	0.80	9:04 a. m.	9:38 a. m.	0.02	0.08	0.26	0.36	0.52	0.61	0.71	0.76							
Mobile, Ala	6	11:34 a. m.	1:10 p. m.	1.23	11:37 a. m.	12:11 p. m.	0.01	0.10	0.21	0.61	0.82	0.98	1.09	1.14							
	12	D. N. a. m.	5:15 a. m.	1.37	2:58 a. m.	3:25 a. m.	0.01	0.12	0.46	0.78	1.06	1.32	1.36								
Modena, Utah	27			0.34														0.34			
Montgomery, Ala	8	2:28 p. m.	3:30 p. m.	0.79	2:28 p. m.	2:47 p. m.	0.00	0.15	0.41	0.68	0.76										
	16	6:48 p. m.	D. N. p. m.	1.73	6:50 p. m.	7:55 p. m.	0.01	0.12	0.24	0.64	0.80	0.88	0.91	0.91	0.91	0.92	0.94	1.40	1.61		
	24	3:15 p. m.	5:30 p. m.	1.11	4:50 p. m.	5:10 p. m.	0.13	0.14	0.41	0.79	0.94										
Moorhead, Minn	6			0.67														0.66			
Mount Tamalpais, Cal	28			T.														T.			
Nantucket, Mass	24–25			2.33														0.59			
Nashville, Tenn	21	8:15 p. m.	D. N. p. m.	1.17	8:19 p. m.	8:31 p. m.	0.01	0.52	0.86	0.97											
	29	4:40 p. m.	8:00 p. m.	1.09	5:10 p. m.	5:32 p. m.	0.03	0.24	0.53	0.68	0.76	0.80									
	29–30	D. N. p. m.	5:00 a. m.	0.71	2:32 a. m.	2:50 a. m.	0.06	0.07	0.26	0.41	0.53										
	31	1:48 a. m.	2:20 a. m.	0.84	1:50 a. m.	2:05 a. m.	0.01	0.45	0.66	0.80											
New Haven, Conn	30	4:47 p. m.	7:40 p. m.	1.00	5:05 p. m.	5:44 p. m.	0.06	0.05	0.10	0.19	0.45	0.57	0.71	0.75	0.93						
New Orleans, La	13	5:05 p. m.	7:23 p. m.	0.61	5:18 p. m.	5:34 p. m.	0.01	0.15	0.35	0.49	0.52										
	18	12:29 p. m.	2:49 p. m.	0.73	12:29 p. m.	1:03 p. m.	0.00	0.11	0.28	0.39	0.41	0.44	0.55	0.67							
	23	4:57 p. m.	7:16 p. m.	0.80	4:59 p. m.	5:10 p. m.	0.01	0.25	0.58	0.61											
	24	3:07 p. m.	4:10 p. m.	1.13	3:34 p. m.	3:48 p. m.	0.03	0.48	0.94	1.09											
New York, N. Y	15	8:00 p. m.	8:55 p. m.	1.33	8:00 p. m.	8:50 p. m.	0.00	0.10	0.21	0.40	0.82	1.05	1.08	1.10	1.14	1.21	1.33				
	17–18	10:45 p. m.	10:45 p. m.	2.13	1:10 a. m.	1:55 a. m.	0.13	0.05	0.19	0.36	0.50	0.57	0.62	0.67	0.72	0.77					
Norfolk, Va	1			0.73														0.60			
North Head, Wash	2			0.13														0.10			
North Platte, Nebr	2			0.61														0.33			
Oklahoma, Okla	29			0.72														0.60			
Omaha, Nebr	11			0.66														0.64			
Oswego, N. Y	16–17	8:18 p. m.	12:40 p. m.	1.88	8:41 p. m.	9:14 p. m.	0.01	0.09	0.27	0.43	0.50	0.54	0.63	0.65							
Palestine, Tex	30	4:47 a. m.	5:32 a. m.	0.68	4:54 a. m.	5:22 a. m.	T.	0.19	0.38	0.44	0.53	0.60	0.67								
Parkersburg, W. Va	21	4:50 p. m.	7:30 p. m.	1.34	6:40 p. m.	7:21 p. m.	0.54	0.08	0.16	0.30	0.40	0.44	0.51	0.60	0.74	0.80					
Pensacola, Fla	3	4:25 a. m.	1:40 p. m.	9.59	7:43 a. m.	8:33 a. m.	0.89	0.09	0.14	0.20	0.23	0.29	0.33	0.36	0.46	0.66	0.83				
					8:33 a. m.	9:23 a. m.	.....	1.03	1.27	1.52	1.66	1.94	2.10	2.34	2.64	2.97	3.27				
					9:23 a. m.	10:13 a. m.	.....	3.51	3.70	3.81	3.94	4.11	4.30	4.51	4.72	4.97	5.05				
					10:13 a. m.	11:03 a. m.	.....	5.18	5.32	5.42	5.64	5.79	5.93	6.13	6.37	6.47	6.58				
					11:03 a. m.	11:53 a. m.	.....	6.66	6.81	7.01	7.17	7.38	7.52	7.57	7.69	7.80	7.85				
					11:53 a. m.	12:20 p. m.	.....	7.95	8.06	8.24	8.49	8.60	8.65								
	7	5:30 p. m.	7:15 p. m.	1.03	5:34 p. m.	6:00 p. m.	0.01	0.20	0.41	0.64	0.89	0.99	1.02								
Peoria, Ill	6	1:50 p. m.	2:57 p. m.	1.23	2:20 p. m.	2:48 p. m.	0.06	0.16	0.44	0.77	1.00	1.09	1.17								
	20–21	11:35 p. m.	12:20 a. m.	1.48	11:42 p. m.	12:17 a. m.	0.01	0.09	0.32	0.56	0.68	0.87	1.33	1.46							
	24	11:55 a. m.	12:25 p. m.	0.56	12:02 p. m.	12:14 p. m.	0.01	0.29	0.48	0.54											
Philadelphia, Pa	13			3.16														0.72			
Phoenix, Ariz	1	7:23 a. m.	10:00 a. m.	1.12	9:12 a. m.	9:42 a. m.	0.25	0.28	0.35	0.43	0.58	0.75	0.80								
Pierre, S. Dak	8	6:35 p. m.	9:25 p. m.	2.06	6:55 p. m.	7:54 p. m.	0.01	0.15	0.34	0.52	0.84	1.27	1.38	1.47	1.55	1.72	1.81	1.93			
Pittsburgh, Pa	12	1:00 p. m.	8:00 p. m.	1.12	7:18 p. m.	7:24 p. m.	0.59	0.45	0.50												
Pocatello, Idaho	8			0.38														0.25			
Point Reyes Light, Cal	(‡)			(‡)														(‡)			
Port Angeles, Wash	12			T.														T.			
Port Huron, Mich	14			0.89														0.36			
Portland, Me	18			0.37														0.13			
Portland, Oreg	31			0.09														0.07			
Providence, R. I	24	5:18 p. m.	7:27 p. m.	1.16	5:24 p. m.	5:48 p. m.	0.01	0.22	0.32	0.38	0.45	0.53									
					6:23 p. m.	6:50 p. m.	0.57	0.11	0.38	0.41	0.42	0.49	0.56								
Pueblo, Colo	8	7:55 p. m.	D. N. p. m.	2.11	8:01 p. m.	8:51 p. m.	0.01	0.13	0.48	0.71	0.82	1.17	1.38	1.58	1.83	1.94	2.04				
	9	6:14 p. m.	6:50 p. m.	0.60	6:24 p. m.	6:39 p. m.	0.01	0.19	0.45	0.54											
Raleigh, N. C	30	1:48 p. m.	2:17 p. m.	0.55	1:51 p. m.	2:05 p. m.	0.01	0.17	0.49	0.53											
		2:32 p. m.	3:40 p. m.	0.96	2:34 p. m.	2:47 p. m.	0.01	0.18	0.40	0.53											
Rapid City, S. Dak	27			0.33														0.16			
Reading, Pa	17–18	5:45 p. m.	1:00 a. m.	5.21	8:26 p. m.	9:16 p. m.	0.06	0.06	0.19	0.42	0.66	0.78	0.81	0.84	0.95	1.07	1.18				
					9:16 p. m.	10:06 p. m.	.....	1.30	1.41	1.49	1.67	1.95	2.21	2.51	2.70	2.77	2.79				
					10:06 p. m.	10:56 p. m.	.....	2.80	2.86	3.02	3.21	3.40	3.52	3.58	3.59	3.62	3.67				
					10:56 p. m.	11:46 p. m.	.....	3.75	3.78	3.79	3.83	3.97	4.14	4.31	4.37	4.48	4.57				
					11:46 p. m.	12:15 a. m.	.....	4.65	4.79	4.87	4.99	5.08	5.13								
Red Bluff, Calif	(‡)			(‡)														(‡)			
Reno, Nev	29			0.07														0.07			

‡ No precipitation occurred during month.

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes, for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during August, 1919, at all stations furnished with self-registering gages.*

Stations.	Date.	Total duration.		Total amount of precipitation.	Excessive rate.		Amount before excessive rate began.	Depths of precipitation (in inches) during periods of time indicated.													
		From—	To—		Began—	Ended—		5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Richmond, Va.	6			0.98														(*)			
Rochester, N. Y.	16–17	5:53 p. m.	D. N. a. m.	1.15	6:38 p. m.	6:46 p. m.	0.03	0.46	0.59												
Roseburg, Oreg.	31			0.02														0.02			
Roswell, N. Mex.	30			0.32														0.31			
Sacramento, Calif.	28			T.														T.			
Saginaw, Mich.	18			0.52														0.52			
St. Joseph, Mo.	15	4:27 p. m.	5:44 p. m.	0.61	4:34 p. m.	4:53 p. m.	0.01	0.12	0.39	0.50	0.55										
St. Louis, Mo.	20	10:30 a. m.	1:15 p. m.	1.10	10:52 a. m.	11:07 a. m.	T.	0.32	0.47	0.53											
					11:45 a. m.	11:56 a. m.	0.55	0.17	0.37	0.38											
St. Paul, Minn.	3	7:15 a. m.	8:55 a. m.	0.98	7:52 a. m.	8:16 a. m.	0.05	0.11	0.25	0.45	0.66	0.87									
Salt Lake City, Utah	8			0.29														0.20			
San Antonio, Tex.	18–19	10:33 p. m.	12:44 a. m.	0.77	10:35 p. m.	11:09 p. m.	0.02	0.11	0.29	0.35	0.45	0.49	0.54	0.60							
San Diego, Calif.	30			0.01														0.01			
Sandusky, Ohio	4	6:45 p. m.	9:25 p. m.	1.10	8:46 p. m.	9:13 p. m.	0.02	0.17	0.43	0.70	0.89	1.01	1.07								
	4–5	10:30 p. m.	8:30 a. m.	1.62	2:13 a. m.	2:30 a. m.	0.30	0.22	0.40	0.50	0.53										
Sandy Hook, N. J.	6	4:05 p. m.	9:45 p. m.	1.23	7:10 p. m.	7:55 p. m.	0.11	0.06	0.13	0.24	0.50	0.78	0.90	0.95	1.01	1.08					
San Francisco, Calif.	28			T.														T.			
San Jose, Calif.	28			0.01														0.01			
San Luis Obispo, Calif.	(‡)			(‡)														(‡)			
Santa Fe, N. Mex.	6	1:25 p. m.	3:55 p. m.	0.88	1:35 p. m.	1:58 p. m.	T.	0.30	0.50	0.59	0.64	0.72									
Sault Ste. Marie, Mich.	21			0.40														0.18			
Savannah, Ga.	11–12	1:11 p. m.	8:15 a. m.	6.07	1:18 p. m.	2:08 p. m.	0.01	0.11	0.31	0.71	0.90	1.10	1.26	1.35	1.46	1.54	1.62				
					2:08 p. m.	2:58 p. m.		1.73	1.88	2.16	2.55	2.84	2.99	3.23	3.54	3.81	4.03				
	14	3:05 p. m.	5:00 p. m.		2:58 p. m.	3:44 p. m.		4.17	4.27	4.47	4.65	4.77	4.86	5.01	5.12	5.18	5.22				
	30	3:50 p. m.	4:50 p. m.	0.98	3:09 p. m.	3:37 p. m.	0.01	0.24	0.37	0.46	0.63	0.75	0.79								
				1.46	3:58 p. m.	4:35 p. m.	0.02	0.24	0.42	0.62	0.84	1.04	1.20	1.40	1.44						
Scranton, Pa.	21			0.35														0.35			
Seattle, Wash.	31			0.04														0.04			
Sheridan, Wyo.	1			0.15														0.11			
Shreveport, La.	9	4:40 p. m.	7:00 p. m.	0.59	4:43 p. m.	5:05 p. m.	0.01	0.14	0.24	0.38	0.50	0.55									
	24	12:30 p. m.	3:25 p. m.	1.07	12:35 p. m.	1:02 p. m.	0.01	0.17	0.36	0.55	0.71	0.83	0.87								
Sioux City, Iowa	6			1.03														0.69			
Spokane, Wash.	4			0.73														0.17			
Springfield, Ill.	6			0.31														0.28			
Springfield, Mo.	27			0.16														0.12			
Syracuse, N. Y.	17			0.39														0.28			
Tacoma, Wash.	31			0.02														0.01			
Tampa, Fla.	9	4:30 p. m.	5:45 p. m.	0.70	4:47 p. m.	5:13 p. m.	0.03	0.13	0.14	0.19	0.25	0.53	0.60								
	11	1:45 p. m.	2:45 p. m.	0.78	2:02 p. m.	2:30 p. m.	0.01	0.18	0.36	0.52	0.65	0.70	0.75								
Tatoosh Island, Wash.	12			0.12														0.04			
Taylor, Tex.	22	5:50 p. m.	8:30 p. m.	0.68	6:46 p. m.	6:59 p. m.	0.06	0.25	0.42	0.54											
Terre Haute, Ind.	17			0.37														0.21			
Thomasville, Ga.	11	2:43 p. m.	6:14 p. m.	1.23	2:45 p. m.	3:19 p. m.	0.01	0.22	0.35	0.47	0.58	0.72	0.93	1.00							
	12	6:30 a. m.	1:20 p. m.	3.10	10:18 a. m.	12:11 p. m.	0.03	0.13	0.26	0.34	0.44	0.56	0.71	0.86	0.97	1.18	1.35	1.76	2.19	2.56	2.93
	24	5:00 p. m.	9:30 p. m.	1.66	5:57 p. m.	6:26 p. m.	0.02	0.10	0.32	0.70	0.91	1.00	1.19								
Toledo, Ohio	5	12:44 p. m.	5:10 p. m.	1.12	12:50 p. m.	1:15 p. m.	0.02	0.20	0.42	0.56	0.67	0.77									
	29–30	10:48 p. m.	D. N. a. m.	0.92	11:26 p. m.	11:51 p. m.	0.04	0.10	0.31	0.45	0.66	0.76									
Tonopah, Nev.	31			0.01														0.01			
Topeka, Kans.	26	9:04 p. m.	D. N. p. m.	1.18	9:35 p. m.	9:46 p. m.	0.05	0.23	0.63	0.67											
	27	9:05 p. m.	D. N. p. m.	0.66	10:04 p. m.	10:25 p. m.	0.01	0.12	0.27	0.48	0.62	0.65									
Trenton, N. J.	6	3:00 p. m.	6:50 p. m.	0.65	4:20 p. m.	4:49 p. m.	0.05	0.07	0.09	0.15	0.20	0.40	0.55								
Valentine, Nebr.	3	1:30 p. m.	3:55 p. m.	1.13	1:52 p. m.	2:16 p. m.	0.01	0.15	0.37	0.68	0.92	1.02									
Vicksburg, Miss.	10	6:02 p. m.	D. N. p. m.	1.35	6:29 p. m.	7:00 p. m.	0.06	0.17	0.38	0.62	0.81	0.93	0.99	1.01							
	11	5:45 p. m.	6:30 p. m.	1.45	5:53 p. m.	6:18 p. m.	0.02	0.22	0.63	0.99	1.32	1.42									
	21	D. N. a. m.	8:45 a. m.	1.29	6:48 a. m.	7:06 a. m.	0.22	0.33	0.59	0.80	0.87										
		3:00 p. m.	6:05 p. m.	1.02	3:02 p. m.	3:25 p. m.	0.01	0.14	0.34	0.56	0.81	0.88									
Walla Walla, Wash.	3			0.06														0.02			
Washington, D. C.	17			0.88														0.67			
Wausau, Wis.	20			0.72														0.59			
Wichita, Kans.	29	4:55 p. m.	7:15 p. m.	1.13	5:01 p. m.	5:19 p. m.	0.01	0.36	0.82	1.05	1.12										
Williston, N. Dak.	5			0.29														0.27			
Wilmington, N. C.	6	10:42 a. m.	1:55 p. m.	1.68	10:51 a. m.	11:33 a. m.	0.04	0.09	0.16	0.34	0.49	0.58	0.65	0.82	0.91	0.96					
	15	7:20 p. m.	10:25 p. m.	1.08	7:34 p. m.	8:10 p. m.	0.08	0.11	0.23	0.40	0.56	0.64	0.70	0.76	0.79						
	30	6:58 p. m.	9:15 p. m.	0.90	7:42 p. m.	8:06 p. m.	0.20	0.18	0.35	0.37	0.51	0.57									
Winnemucca, Nev.	29			T.														T.			
Wytheville, Va.	12			0.41														0.30			
Yankton, S. Dak.	3	7:15 p. m.	8:10 p. m.	0.63	7:22 p. m.	7:36 p. m.	0.01	0.28	0.50	0.59											
	10	12:15 p. m.	2:15 p. m.	0.63	12:22 p. m.	12:31 p. m.	0.02	0.36	0.50												
	12	4:30 a. m.	5:15 p. m.	0.54	4:32 a. m.	4:51 a. m.	0.01	0.20	0.37	0.40	0.51										
Yellowstone Park, Wyo.	3			0.21														0.10			

* Self-register not in use.

‡ No precipitation occurred during month.

TABLE III.—*Data furnished by the Canadian Meteorological Service, August, 1919.*

Stations.	Altitude above mean sea level, Jan. 1, 1918.	Pressure.			Temperature of the air.						Precipitation.		
		Station reduced to mean of 24 hours.	Sea level reduced to mean of 24 hours.	Departure from normal.	Mean max.+ mean min.÷ 2.	Departure from normal.	Mean maximum.	Mean minimum.	Highest.	Lowest.	Total.	Departure from normal.	Total snowfall.
	Feet.	*Inches.*	*Inches.*	*Inches.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*Inches.*	*Inches.*	*Inches.*
St. Johns, N. F.	125												
Sydney, C. B. I.	48	29.93	29.98	+0.03	64.4	+1.1	74.0	54.9	81.0	44.0	3.98	+0.36	
Halifax, N. S.	88	29.84	29.94	− .02	62.8	+0.8	71.0	54.4	78.2	44.4	8.29	+3.94	
Yarmouth, N. S.	65	29.86	29.93	− .04	60.8	+0.6	66.4	55.2	75.5	44.2	4.86	+0.85	
Charlottetown, P. E. I.	38	29.88	29.92	− .02	65.6	+1.3	72.9	58.3	80.0	47.0	5.19	+1.45	
Chatham, N. B.	28	29.88	29.90	− .03	63.5	+0.3	73.8	53.2	85.0	43.0	2.55	−1.49	
Father Point, Que.	20	29.83	29.85	− .06	55.9	+0.3	64.1	47.8	79.0	42.6	2.94	−0.11	
Quebec, Que.	296	29.58	29.90	− .03	63.3	+0.2	71.8	54.9	79.8	43.8	3.27	−0.56	
Montreal, Que.	187	29.69	29.89	− .06	66.3	+0.1	74.1	58.5	83.9	48.2	2.56	−1.01	
Stonecliffe, Ont.	489	29.28	29.88	− .08	57.3	−5.9	77.0	37.7	90.0	28.0	2.32	−0.63	
Ottawa, Ont.	236	29.64	29.90	− .06	66.8	+2.0	77.5	56.1	90.0	43.0	1.58	−1.45	
Kingston, Ont.	285	29.61	29.91	− .07	68.1	+1.1	76.4	59.8	84.3	48.2	2.24	−0.14	
Toronto, Ont.	379	29.51	29.90	− .09	67.9	+1.9	77.8	57.9	92.2	47.6	2.17	−0.59	
Cochrane, Ont.	930				60.1		69.2	51.0	82.0	39.0	6.90		
White River, Ont.	1,244	28.56	29.86	− .10	57.8	+1.4	71.1	44.6	86.5	30.0	3.72	+0.42	
Port Stanley, Ont.	592	29.30	29.93	− .07	66.3	+0.4	75.8	56.8	86.2	44.8	2.18	−0.24	
Southampton, Ont.	656	29.20			65.4	+1.6	73.6	57.3	84.8	45.2	2.08	−0.17	
Parry Sound, Ont.	688	29.22	29.90	− .08	66.0	+1.5	76.0	56.0	91.0	43.0	4.40	+1.68	
Port Arthur, Ont.	644	29.18	29.83	− .13	63.0	+3.5	73.0	53.0	82.0	39.0	2.72	−0.03	
Winnipeg, Man.	760	29.07	29.88	− .06	65.8	+2.4	77.9	53.7	93.4	36.0	3.15	+0.48	
Minnedosa, Man.	1,690	28.12	29.90	− .04	65.0	+5.6	79.1	50.9	98.0	34.0	1.03	−1.07	
Le Pas, Man.	860												
Qu'Appelle, Sask.	2,115	27.68	29.85	− .08	65.5	+4.0	80.0	51.0	93.0	39.0	0.58	−1.06	
Medicine Hat, Alb.	2,144	27.61	29.81	− .11	70.5	+4.8	85.3	55.8	95.0	41.0	0.06	−1.61	
Moose Jaw, Sask.	1,759				68.4		84.2	52.6	97.0	38.0	2.20		
Swift Current, Sask.	2,392	27.35	29.91	− .02	67.5	+3.5	82.5	52.5	92.0	40.0	3.22	+1.31	
Calgary, Alb.	3,428	26.45	29.95	+ .04	63.6	+4.2	78.0	49.1	92.0	41.0	3.80	+1.66	
Banff, Alb.	4,521	25.44	29.94	+ .03	57.9	+1.6	73.6	42.2	83.8	31.0	2.25	−0.28	
Edmonton, Alb.	2,150	27.62	29.86	− .06	61.5	+2.7	75.1	47.9	87.0	35.0	0.95	−1.18	
Prince Albert, Sask.	1,450	28.34	29.89	− .03	64.4	+5.5	76.8	52.1	92.0	40.0	3.14	+0.99	
Battleford, Sask.	1,592	28.15	29.85	− .06	64.9	+2.3	79.3	50.5	91.0	42.0	2.49	+0.13	
Kamloops, B. C.	1,262												
Victoria, B. C.	230	29.79	30.04	+ .03	58.8	+0.1	66.7	50.9	80.4	47.7	0.34	−0.26	
Barkerville, B. C.	4,180												
Triangle Island, B. C.	680												
Prince Rupert, B. C.	170												
Hamilton, Ber.	151	29.97	30.13	+ .03	79.0	−0.6	84.7	73.2	90.2	69.0	6.92	+0.82	

SEISMOLOGY.

TABLE 1.—*Noninstrumental earthquake reports, August, 1919.*

Day.	Approximate time, Greenwich Civil.	Station.	Approximate latitude.	Approximate longitude.	Intensity Rossi-Forel.	Number of shocks.	Duration.	Sounds.	Remarks.	Observer.
		CALIFORNIA.								
	H. m.		° ′	° ′			Sec.			
1	12 10	Glennville	35 45	118 42	3	2	Few	Faint	Slight rattle of windows	C. H. Likely.
10	4 50	Berkeley	37 22	118 24	3	2	1	None	Felt by several	William Barth.
26	12 15	Ojai	34 25	119 12	3	3	2	Rattling	Felt by many	Wm. H. Duncan.
26	12 13	San Luis Obispo	35 17	120 40	3	1	1	None	Felt by several	U. S. Weather Bureau.
26	15 00	Ojai	34 25	119 12	3	1		None	Felt by several	Wm. H. Duncan.

TABLE 2.—*Instrumental seismological reports, August, 1919.*

(Time used: Mean Greenwich, midnight to midnight. Nomenclature: International.)

[For significance of symbols see REVIEW for January, 1919, p. 59.]

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.

Alabama. *Mobile. Spring Hill College.* Earthquake Station. Cyril Ruhlmann, S. J.

Lat., 30° 41′ 44″ N.; long., 88° 08′ 46″ W. Elevation, 60 meters.

Instrument: Wiechert 80 kg.; astatic, horizontal pendulum.

(No earthquake recorded during August, 1919.)

Alaska. *Sitka. Magnetic Observatory.* U. S. Coast and Geodetic Survey. F. P. Ulrich.

Lat., 57° 03′ 00″ N.; long., 135° 30′ 06″ W. Elevation, 15.2 meters.

Instruments: Two Bosch-Omori, 10 and 12 kg.

Instrumental constants..		V	T_0
	E	10	17
	N	10	15

No earthquake recorded during August, 1919.

Arizona. *Tucson. Magnetic Observatory.* U. S. Coast and Geodetic Survey. Wm. H. Cullum.

Lat., 32° 14′ 48″ N.; long., 110° 50′ 06″ W. Elevation, 769.6 meters.

Instruments: Two Bosch-Omori, 10 and 12 kg.

Instrumental constants..		V	T_0
	E	10	15
	N	10	18

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
			H. m. s.	Sec.	μ	μ	Km.	
Aug. 29	.....	L_E	6 38 50	23	.....	.....	.....	N. — not in operation from 23d to 31st.
		M_E	6 48 20	20	20	.....	.....	
		C_E	7 00 ..	18	.....	.....	.....	
		F_E	7 11 ..	.....	.....	.....	.....	
29	.....	e_E	23 10 30	4	10	.....	.....	Slight near-by shock.
		F_E	23 16 ..	.....	.....	.....	.....	
31	.....	P_E	17 34 01	4	.....	.....	.....	
		eS_E	17 45 01	.....	.....	.....	.....	
		eL_E	18 07 20	.....	.....	.....	.....	
		M_E	18 15 20	17	10	.....	.....	
		C_E	18 20 ..	16	.....	.....	.....	
		F_E	18 31 ..	15	.....	.....	.....	

California. *Berkeley. University of California.*

Lat., 37° 52′ 16″ N.; long., 122° 15′ 37″ W. Elevation, 85.4 meters.

(*See* Bulletin of the Seismographic Stations, University of California.

California. *Mount Hamilton. Lick Observatory.*

Lat., 37° 20′ 24″ N.; long., 121° 38′ 34″ W. Elevation, 1,281.7 meters.

(*See* Bulletin of the Seismographic Stations, University of California.)

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.

California. *Point Loma. Raja Yoga Academy.* F. J. Dick.

Lat., 32° 43′ 03″ N.; long., 117° 15′ 10″ W. Elevation, 91.4 meters.

Instrument: Two-component, C. D. West seismoscope.

			H. m. s.	Sec.	μ	μ	Km.	
Aug. 21	.....	.....	.....	.....	100	100	.....	Tremors during 24 hours preceeding $15^h\ 00^m$ on date given.

Colorado. *Denver. Sacred Heart College.* Earthquake Station. A. W. Forstall, S. J.

Lat., 39° 40′ 36″ N.; long., 104° 56′ 54″ W. Elevation, 1,655 meters.

Instrument: Wiechert 80 kg., astatic, horizontal pendulum.

			H. m. s.	Sec.	μ	μ	Km.	
Aug. 9	u. e.	L	5 21 ..	.....	.....	.....	.....	Sinusoidal.
		F	5 24 ..	.....	.....	.....	.....	
10	.....	.....	3 to 5	.....	.....	.....	.....	Activity. Stronger on N–S.
22	.....	.....	3 to 9	.....	.....	.....	.....	Activity on E–W.
27–28	.....	.....	11 to 1	.....	.....	.....	.....	Activity on E–W. Sinusoidal; long period; small amplitude.
31	.....	.....	.....	.....	.....	.....	.....	Waves at intervals during the day.

District of Columbia. *Washington. U. S. Weather Bureau.*

Lat., 38° 54′ 12″ N.; long., 77° 03′ 03″ W. Elevation, 21 meters.

Instrument: Marvin (vertical pendulum), undamped. Mechanical registration.

Instrumental constants..	V	T_0
	110	6.4

			H. M. S.	Sec.	μ	μ	Km.	
Aug. 8	.....	P	5 11 22	.....	.....	.....	6,480	L undiscernible.
		S	5 19 24	.....	.....	.....	.....	
		F	5 30 ..	.....	.....	.....	.....	
18	.....	e	17 21 05	.....	.....	.....	.....	
		L	17 39 50	20	.....	.....	.....	
		F	17 55 ..	.....	.....	.....	.....	
22	.....	P	8 55 07	.....	.....	.....	1,990?	
		S?	8 58 25	.....	.....	.....	.....	
		F	9 05 ..	.....	.....	.....	.....	
24	.....	e	5 25 ca	.....	.....	.....	.....	Amplitudes very small. Phases undeterminable
		F	5 50 ..	.....	.....	.....	.....	
29	.....	eP	6 06 22	.....	.....	.....	5,140?	
		S?	6 13 12	.....	.....	.....	.....	
		eL	6 21 ..	.....	.....	.....	.....	
		L	6 56 ..	20	.....	.....	.....	
		F	7 35 ..	.....	.....	.....	.....	
30	.....	P?	6 09 36	.....	.....	.....	.....	
		S?	6 13 20	.....	.....	.....	.....	
		F	6 30 ..	.....	.....	.....	.....	
31	.....	P	17 40?..	.....	.....	.....	.....	Small amplitude lasting about one hour. Clock not running.

TABLE 2.—*Instrumental seismological reports, August, 1919*—Continued.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
District of Columbia. *Washington. Georgetown University.* F. A. Tondorf, S. J.								
Lat., 38° 54′ 25″ N.; long., 77° 04′ 24″ W. Elevation, 42.4 meters. Subsoil: Decayed diorite.								
Instruments: Wiechert 200 kg. astatic horizontal pendulums, 80 kg. vertical.								
Instrumental constants..				V: E 165, N 143, Z 80	T_0: E 5.4, N 5.2, Z 3.0	ε: E 0, N 0, Z 0		
			H. m. s.	Sec.	μ	μ	Km.	
Aug. 24	.....	e	5 31 26	.....	.....	.....	.....	Heavy microseisms.
	.....	eL_E?..	5 40 12	8	.....	.....	.....	
	.....	F	6 15 ..	.....	.....	.....	.....	
27	.....	e	5 39 ..	.....	.....	.....	.....	Heavy microseisms.
	.....	L	6 25 25	16	.....	.....	.....	
	.....	F	6 47 ..	.....	.....	.....	.....	
Hawaii. *Honolulu. Magnetic Observatory.* U. S. Coast and Geodetic Survey. Frank Neumann.								
Lat., 21° 19′ 12″ N.; long., 158° 03′ 48″ W. Elevation, 15.2 meters.								
Instrument: Milne seismograph of the Seismological Committee of the British Association.								
Instrumental constant..T_0 18.4. Sensitivity, 0.40″.								
(Report for August, 1919, not received.)								
Illinois. *Chicago.* University of Chicago. U. S. Weather Bureau.								
Lat., 41° 47′ N.; long., 87° 37′ W. Elevation, 180.1 meters.								
Instruments: Two Milne-Shaw horizontal pendulums, 0.45 kg.								
Instrumental constants..				V: E. 150, N. 150	T_0: 12, 8	ε: 20:1, 20:1	Sensivity: 1″ arc tilt=26.6 mm.; 1″ arc tilt=13.2 mm.	
			H. M. S.	Sec.	μ	μ	Km.	
Aug. 2	.....	eP?..	22 59 ca	.....	.....	.....	.....	
	.....	S.....	23 02 50	.....	.....	.....	.....	
	.....	L.....	23 05 20	.....	.....	.....	.....	
	.....	F.....	23 20 ..	.....	.....	.....	.....	
3	.....	eL.....	16 34 ..	.....	.....	.....	.....	
	.....	F.....	17 30 ..	.....	.....	.....	.....	
3	.....	e?	18 33 ..	.....	.....	.....	.....	
	.....	L.....	18 50 ..	.....	.....	.....	.....	
	.....	L.....	19 00 ..	18	.....	.....	.....	
	.....	F.....	20 10 ..	.....	.....	.....	.....	
8	.....	P.....	5 11 38	.....	.....	.....	7080	
	.....	S.....	5 20 11	.....	.....	.....	.....	
	.....	eL?...	5 33 ..	.....	.....	.....	.....	
	.....	L.....	5 36 ..	25	.....	.....	.....	
	.....	L.....	5 42 30	18	.....	.....	.....	
	.....	F.....	6 10 ca	.....	.....	.....	.....	
15	.....	eP.....	4 30 05	.....	.....	.....	9,000	
	.....	S.....	4 40 15	.....	.....	.....	.....	
	.....	L.....	4 53 20	.....	.....	.....	.....	
	.....	F.....	5 20 ..	.....	.....	.....	.....	
18	.....	e.....	11 31 ..	.....	.....	.....	.....	
	.....	eL.....	11 36 40	.....	.....	.....	.....	
	.....	F.....	11 50 ..	.....	.....	.....	.....	
18	.....	P?....	17 05 49	.....	.....	.....	13,000?	
	.....	S.....	17 18 55	.....	.....	.....	.....	
	.....	L?....	17 31 ..	.....	.....	.....	.....	
	.....	L.....	17 50 30	20	.....	.....	.....	
	.....	L.....	18 10 ..	15	.....	.....	.....	
	.....	F.....	19 00 ..	.....	.....	.....	.....	
18	.....	eL.....	21 44 ..	.....	.....	.....	.....	
	.....	L.....	21 50 ..	18	.....	.....	.....	
	.....	L.....	21 56 ..	15	.....	.....	.....	
	.....	F.....	22 30 ..	.....	.....	.....	.....	
22	.....	P.....	8 56 17	.....	.....	.....	4,170	
	.....	S.....	9 01 14	.....	.....	.....	.....	
	.....	L?....	9 05 22	.....	.....	.....	.....	

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
Illinois. *Chicago. University of Chicago*—Continued.								
			H. m. s.	Sec.	μ	μ	Km.	
Aug. 24	.....	e.....	5 24 44	.....	.....	.....	.....	Amplitude small.
	.....	F.....	5 30 ..	.....	.....	.....	.....	Phases indeterminate.
24	.....	e.....	12 51 15	.....	.....	.....	.....	Amplitude small.
	.....	F.....	13 15 ca	.....	.....	.....	.....	Phases indeterminate.
24	.....	eL....	19 51 ca	.....	.....	.....	.....	
	.....	F.....	20 00 ..	.....	.....	.....	.....	
27	.....	P.....	5 45 45	.....	.....	.....	5,830?	
	.....	S?....	5 53 12	.....	.....	.....	.....	
	.....	L.....	6 01 45	.....	.....	.....	.....	
	.....	L.....	6 12 ..	20	.....	.....	.....	
	.....	L.....	6 25 ..	18	.....	.....	.....	
	.....	L.....	6 31 ..	15	.....	.....	.....	
	.....	F.....	8 00 ca	.....	.....	.....	.....	
29	.....	P.....	6 05 17	.....	.....	.....	5,190	
	.....	S.....	6 12 10	.....	.....	.....	.....	
	.....	L?....	6 19 10	.....	.....	.....	.....	
	.....	L.....	6 22 45	18	.....	.....	.....	
	.....	L.....	6 46 ..	30	.....	.....	.....	
	.....	L.....	6 52 ..	20	.....	.....	.....	
	.....	L.....	7 01 ..	16	.....	.....	.....	
	.....	F.....	8 30 ..	.....	.....	.....	.....	
30	.....	P?....	6 09 36	.....	.....	.....	.....	
	.....	S?....	6 15 17	.....	.....	.....	.....	
	.....	L?....	6 20 20	.....	.....	.....	.....	
	.....	F.....	7 00 ..	.....	.....	.....	.....	
31	.....	e.....	0 51 20	.....	.....	.....	.....	
	.....	F.....	1 10 ..	.....	.....	.....	.....	
31	.....	P.....	17 39 12	.....	.....	.....	9,010	
	.....	PR...	17 46 03	.....	.....	.....	.....	
	.....	S.....	17 49 05	.....	.....	.....	.....	
	.....	L.....	18 16 25	.....	.....	.....	.....	
	.....	L.....	18 20 ..	18	.....	.....	.....	
	.....	L.....	18 40 ..	16	.....	.....	.....	
	.....	F.....	20 20 ca	.....	.....	.....	.....	
Kansas. *Lawrence. University of Kansas.* Department of Physics and Astronomy. F. E. Kester.								
Lat., 38° 57′ 30″ N.; long., 95° 14′ 58″ W. Elevation, 301.1 meters.								
Instrument: Wiechert.								
Instrumental constants..				V: E 177, N 205	T_0: 3.4, 3.4	ε: 4:1, 4:1		
(Report for August, 1919, not received.)								
Maryland. *Cheltenham. Magnetic Observatory.* U. S. Coast and Geodetic Survey. George Hartnell.								
Lat., 38° 44′ 00″ N.; long., 76° 50′ 30″ W. Elevation, 71.6 meters.								
Instruments: Two Bosch-Omori, 10 and 12 kg.								
Instrumental constants..				V: E 10, N 10	T_0: 14, 14			
			H. m. s.	Sec.	μ	μ	Km.	
Aug. 29	.....	eP_E...	6 06 31	.....	.....	.....	.....	L_N is doubtful; it may come three minutes or more earlier.
		eP_N...	6 06 38	.....	.....	.....	.....	
		eL_E...	6 56 20	.....	.....	.....	.....	
		eL_N...	6 55 20	25	.....	.....	.....	
		M_N....	7 06 25	20	.....	10	.....	
		C_N....	7 18 ..	17	.....	.....	.....	
		F_E....	7 05 ..	.....	.....	.....	.....	
		F_N....	7 50 ..	.....	.....	.....	.....	
31	.....	P_E....	17 40 53	5	.....	.....	.....	
		eP_N...	17 41 25	.....	.....	.....	.....	
		S_E....	17 50 33	8	.....	.....	.....	
		eL_E...	18 27 40	.....	.....	.....	.....	
		eL_N...	18 12 30	28	.....	.....	.....	
		M_E....	18 31 35	18	.....	.....	.....	
		M_N....	18 39 ..	18	.....	.....	.....	
		F_E....	18 42 ..	.....	.....	.....	.....	
		F_N....	18 59 ..	.....	.....	.....	.....	

TABLE 2.—*Instrumental seismological reports, August, 1919*—Continued.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.

Massachusetts. *Cambridge. Harvard University Seismographic Station.* J. B. Woodworth.

Lat., 42° 22′ 36″ N.; long., 71° 06′ 59″ W. Elevation, 5.4 meters. Foundation: Glacia sand over clay.

nstruments: Two Bosch-Omori 100 kg. horizontal pendulums (mechanical registration)

Instrumental constants..		V	T_0	ε
	E	80	23	0
	N	50	25	4:1

(Report for August, 1919, not received.)

Missouri. *Saint Louis. St. Louis University.* Geophysical Observatory. J. B. Goesse, S. J.

Lat., 38° 38′ 15″ N.; long., 90° 13′ 58″ W. Elevation, 160.4 meters. Foundation: 12 feet of tough clay over limestone of Mississippi system, about 300 feet thick.

Instrument: Wiechert 80 kg. astatic, horizontal pendulum.

Instrumental constants..	V	T_0	ε
	80	7	5:1

(Report for August, 1919, not received.)

New York. *Ithaca. Cornell University.* Heinrich Ries.

Lat., 42° 26′ 58″ N.; long., 76° 29′ 09″ W. Elevation, 242.6 meters.

Instruments: Two Bosch-Omori, 25 kg., horizontal pendulums (mechanical registration.

Instrumental constants..		V	T_0	ε
	E	13	22	4:1
	N	14	25	4:1

(Report for August, 1919, not received.)

New York. *New York. Fordham University.* D. H. Sullivan, S. J.

Lat., 40° 51′ 47″ N.; long., 73° 53′ 08″ W. Elevation, 23.9 meters.

Instrument: Wiechert, 80 kg.

Instrumental constants..		V	T_0	ε
	E	72	5.0	0
	N	72	5.0	0

(Report for August, 1919, not received.)

Panama Canal Zone. *Balboa Heights.* Governor, Panama Canal.

Lat., 8° 57′ 39″ N.; long., 79° 33′ 29″ W. Elevation, 27.6 meters.

Instruments: Two Bosch-Omori, 100 kg.

Instrumental constants..	V	T_0
	35	20

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
			H. m. s.	*Sec.*	*μ*	*μ*	*Km.*	
Aug. 19	.....	P	2 11 14	.....	.....	.....	160	
		P_E	2 11 20	.....	.....	.....	.....	
		L ..	2 11 31	20	.....	.....	.....	
		L_E	2 11 37	20	.....	.....	.....	
		.....	2 11 42	.....	.....	*200	.....	
		M_E	2 11 43	.....	*800	.....	.....	
		F	2 13 45	.....	.....	.....	.....	
		F_E	2 13 50	.....	.....	.....	.....	

*Trace amplitude.

Porto Rico. *Vieques. Magnetic Observatory.* U. S. Coast and Geodetic Survey. W. M. Hill.

Lat., 19° 09′ N.; long., 65° 27′ W. Elevation, 19.8 meters.

Instruments: Two Bosch-Omori.

Instrumental constants..		V	T_0
	E	10	18
	N	10	20

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
			H. m. s.	*Sec.*	*μ*	*μ*	*Km.*	
Aug. 3	.....	P_E	16 38 26	2	.....	.....	.....	Probably from Porto Rico, N, not registering.
		L_E	16 38 46	.....	.....	.....	.....	
		M_E	16 38 58	.....	60	.....	.....	
		C_E	16 40 ..	.....	.....	.....	.....	
		F_E	16 43 ..	.....	.....	.....	.....	

Porto Rico. *Vieques. Magnetic Observatory*—Continued.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
			H. m. s.	*Sec.*	*μ*	*μ*	*Km.*	
Aug. 9	.....	P	11 49 34	.....	20	20	.....	Apparently local.
		F	11 54 ..	.....	.....	.....	.....	
22	.....	iP	8 50 57	2	.....	.....	.....	Probably from Porto Rico.
		L	8 51 20	.....	.....	.....	.....	
		M_E ...	8 51 34	.....	90	.....	.....	
		M_N ...	8 51 28	.....	.....	130	.....	
		C	8 55 ..	.....	.....	.....	.....	
		F	8 59 ..	.....	.....	.....	.....	
30	.....	iP	6 04 08	3	.....	.....	.....	Probably from Porto Rico. Felt by a few persons in Vieques.
		eL_E ...	6 05 12	.....	.....	.....	.....	
		eL_N ...	6 05 14	.....	.....	.....	.....	
		M_E	6 05 35	.....	110	.....	.....	
		M_N	6 05 38	.....	.....	130	.....	
		C	6 07 ..	5	.....	.....	.....	
		F	6 14 ..	.....	.....	.....	.....	

Vermont. *Northfield. U. S. Weather Bureau.* Wm. A. Shaw.

Lat., 44° 10′ N.; long., 72° 41′ W. Elevation, 256 meters.

Instruments: Two Bosch-Omori, mechanical registration.

Instrumental constants..		V	T_0
	E	10	15
	N	10	16

(No earthquakes recorded for August, 1919.)

Canada. *Ottawa. Dominion Astronomical Observatory.* Earthquake Station. Otto Klotz.

Lat., 45° 23′ 38″ N.; long., 75° 42′ 57″ W. Elevation, 83 meters.

Instruments: Two Bosch photographic horizontal pendulums, one Spindler & Hoyer 80 kg. vertical seismograph.

Instrumental constants..	V	T_0
	120	26

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
			H. m. s.	*Sec.*	*μ*	*μ*	*Km.*	
Aug. 18	.....	i_N	5 16 18	.....	.....	.....	.....	May not be seismic.
		e_E	5 16 20	.....	.....	.....	.....	
		i	5 21 32	.....	.....	.....	.....	
		i_N	5 33 28	.....	.....	.....	.....	
		i_E	5 39 34	.....	.....	.....	.....	
		i_N	5 39 38	.....	.....	.....	.....	
		eL	5 42 40	30	.....	.....	.....	
			to					
			5 52 ..	.....	.....	.....	.....	
		L_E	6 00 ..	16	.....	.....	.....	
			to					
			6 04 ..	.....	.....	.....	.....	
		F	6 05 ..	.....	.....	.....	.....	
24	.....	e	5 31 ..	6	.....	.....	.....	
			to					
			5 56 ..	.....	.....	.....	.....	
		e	5 59 ..	7.5	.....	.....	.....	
			to					
			6 25 ..	.....	.....	.....	.....	
27	.....	e_E	5 39 44	.....	.....	.....	.....	
		i_N	5 39 45	.....	.....	.....	.....	
		i	5 46 10	.....	.....	.....	.....	
		e_E	5 48 54	.....	.....	.....	.....	
		e_N	5 49 00	.....	.....	.....	.....	
		eL	6 12 10	12.5	.....	.....	.....	
			to					
			6 26 ..	.....	.....	.....	.....	
		eL	6 27 04	17	.....	.....	.....	
			to					
			6 37 ..	.....	.....	.....	.....	
		eL	6 39 30	20	.....	.....	.....	
		F	6 50 ..	.....	.....	.....	.....	

Canada. *Toronto. Dominion Meteorological Service.*

Lat., 43° 40′ 01″ N.; long., 79° 23′ 54″ W. Elevation, 113.7 meters. Subsoil: Sand and clay.

Instrument: Milne horizontal pendulum, North; in the meridian.

	T_0
Instrumental constant..	18.

Pillar deviation, 1 mm. swing of boom=0.45″.

(Report for August, 1919, not received.)

TABLE 2.—*Instrumental seismological reports, August, 1919*—Contd.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.

Canada. *Victoria, B. C. Dominion Meteorological Service.*

Lat., 48° 24′ N.; long., 123° 19′ W. Elevation, 67.7 meters. Subsoil: Rock.

Instrument: Wiechert, vertical; Milne horizontal pendulum, North. In the meridian.

Instrumental constant T_0..18. Pillar deviation, 1 mm. swing of boom=0.54″.

(Report for August, 1919, not received.)

SEISMOLOGICAL DISPATCHES.[1]

On Board U. S. S. New Mexico, Saturday, Aug 2.

The *New Mexico* trembled from bow to stern as if she had struck an uncharted reef, and the navigating officer sounded "collision quarters" on the flagship's siren. Sailors in the foretop said the basketmasts of the war ships swayed like poplar trees in a gale.

Wireless telephone messages were received from the five other dreadnaughts reporting that they felt the shocks. The *Mississippi*, which was farther offshore, reported heavy vibrations.—*Associated Press.*

On Board U. S. S. New Mexico, Saturday, August 2.

Six dreadnaughts of the Pacific Fleet were shaken severely by a double earthquake shock at 4:18 o'clock this afternoon 20 miles off the coast of the State of Colima, Mexico. None of the warships reported any damage.—*Associated Press.*

Beach Haven, N. J., August 5, 1919.

A shock was felt here about midnight.—*Special Observer.*

LATE REPORTS.

TABLE 3.—*Late reports (instrumental).*

California. *Point Loma. Raja Yoga Academy.* F. J. Dick.

Lat., 32° 43′ 03″ N.; long., 117° 15′ 10″ W. Elevation, 91.4 meters.

Instrument: Two-component, C. D. West seismoscope.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
			H. m. s.	*Sec.*	μ	μ	*Km.*	
July 3	.....	.....	.....	.....	50	50	.....	Tremors during 24 hours preceding $15^h\ 00^m$ on dates given.
15	.....	.....	.....	.....	100	100	.....	

[1] Reported by the organization indicated and collected by the seismological station at Georgetown University, Washington D. C.

TABLE 3.—*Late reports (instrumental)*—Continued.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.

Hawaii. *Honolulu. Magnetic Observatory.* U. S. Coast and Geodetic Survey. Frank Neumann.

Lat., 21° 19′ 12″ N.; long., 158° 03′ 48″ W. Elevation, 15.2 meters.

Instrument: Milne seismograph of the Seismological Committee of the British Association.

Instrumental constant T_0..18.1. Sensitiveness 0.40 arc tilt″=1 mm.

				H. m. s.	*Sec.*	μ	μ	*Km.*	
July	6	.....	eP.....	7 15 18	18	.....	.....	.....	P is faint and difficult to place definitely.
		.....	S.....	7 23 30	.....	.....	.....	.....	
		.....	L.....	7 33 24	.....	.....	.....	.....	
		.....	M.....	7 35 30	20	*200	.....	.....	
		.....	C.....	7 39 ..	20	.....	.....	.....	
		.....	F.....	7 49 ..	.....	.....	.....	.....	
	7	.....	eP.....	14 09 12	18	.....	.....	.....	None of the phases sharply defined.
		.....	eS.....	14 15 18	17	.....	.....	.....	
		.....	eL.....	14 19 ..	.....	.....	.....	.....	
		.....	M.....	14 27 06	16	*500	.....	.....	
		.....	C.....	14 31 ..	16	.....	.....	.....	
		.....	F.....	14 51 ..	20	.....	.....	.....	
	8	.....	eP.....	21 31 00	20	.....	.....	.....	Early portion of record (before L) might be microseisms or caused by minor shocks.
		.....	L.....	22 38 30	.....	.....	.....	.....	
		.....	M.....	22 55 00	16	.....	.....	.....	
		.....	C.....	22 59 ..	.....	.....	.....	.....	
		.....	F.....	24 12 ..	20	.....	.....	.....	
	14	.....	eP.....	13 50 18	.....	.....	.....	.....	eP quite faint.
		.....	L.....	13 59 30	.....	.....	.....	.....	
		.....	M.....	14 05 00	16	*200	.....	.....	
		.....	C.....	14 07 ..	.....	.....	.....	.....	
		.....	F.....	14 57 ..	17	.....	.....	.....	
	16	.....	eP.....	18 20 54	20	.....	.....	.....	eP quite faint.
		.....	L.....	18 29 24	.....	.....	.....	.....	
		.....	M.....	18 32 30	19	*300	.....	.....	
		.....	C.....	18 35 ..	.....	.....	.....	.....	
		.....	F.....	19 04 ..	.....	.....	.....	.....	
	24	.....	eP.....	2 29 42	18	.....	.....	.....	eP quite faint.
		.....	L.....	3 04 ..	.....	.....	.....	.....	
		.....	M.....	3 09 00	16	*300	.....	.....	
		.....	C.....	3 15 ..	.....	.....	.....	.....	
		.....	F.....	3 31 ..	19	.....	.....	.....	
	25	.....	eP.....	19 13 42	18	.....	.....	.....	
		.....	L.....	19 21 ..	.....	.....	.....	.....	
		.....	M.....	19 26 30	.....	*300	.....	.....	
		.....	C.....	19 28 24	.....	.....	.....	.....	
		.....	F.....	19 45 ..	18	.....	.....	.....	
	31	.....	eP.....	7 15 00	19	.....	.....	.....	eP quite faint.
		.....	L.....	7 24 01	.....	.....	.....	.....	
		.....	M.....	7 31 00	19	*400	.....	.....	
		.....	C.....	7 34 ..	16	.....	.....	.....	
		.....	F.....	8 09 ..	16	.....	.....	.....	

*Trace amplitude.

Chart I. Hydrographs of Several Principal Rivers, August, 1919.

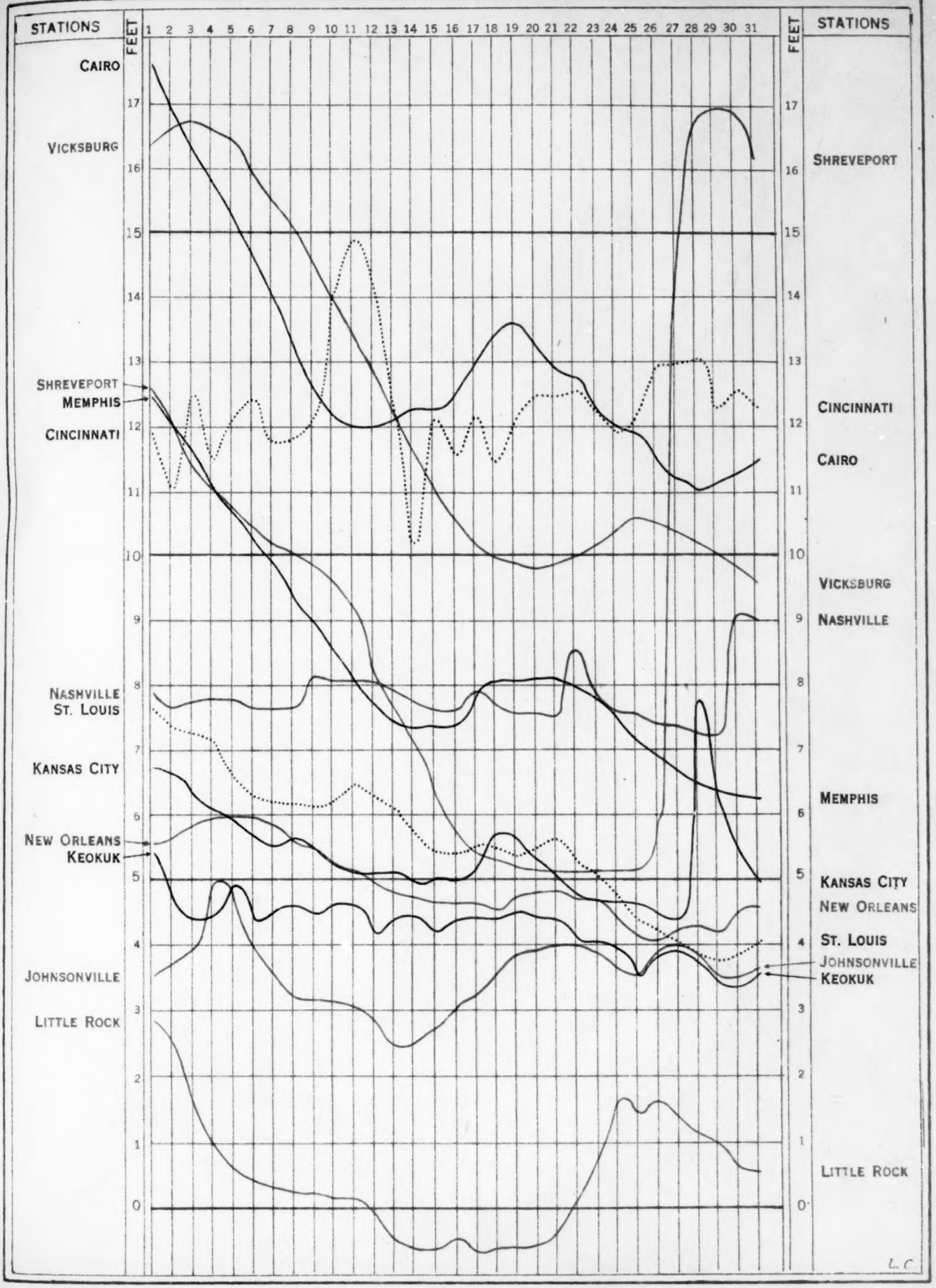


Chart II. Tracks of Centers of High Areas, August, 1919.

(Plotted by R. H. Weightman, Meteorologist.)

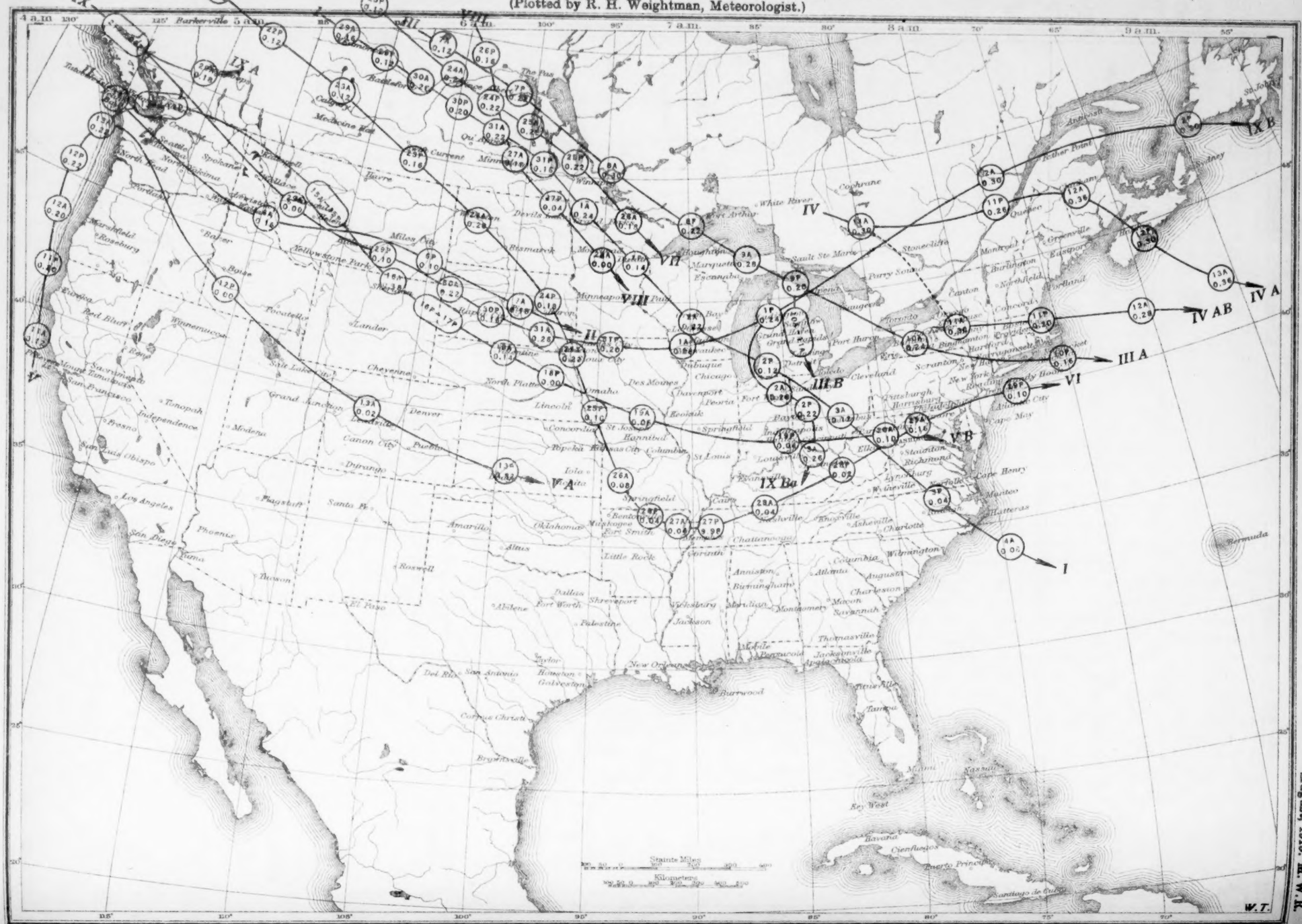


Chart III. Tracks of Centers of Low Areas, August, 1919.

(Plotted by R. H. Weightman, Meteorologist.)

Chart IV. Departure (°F.) of the Mean Temperature from the Normal, August, 1919.

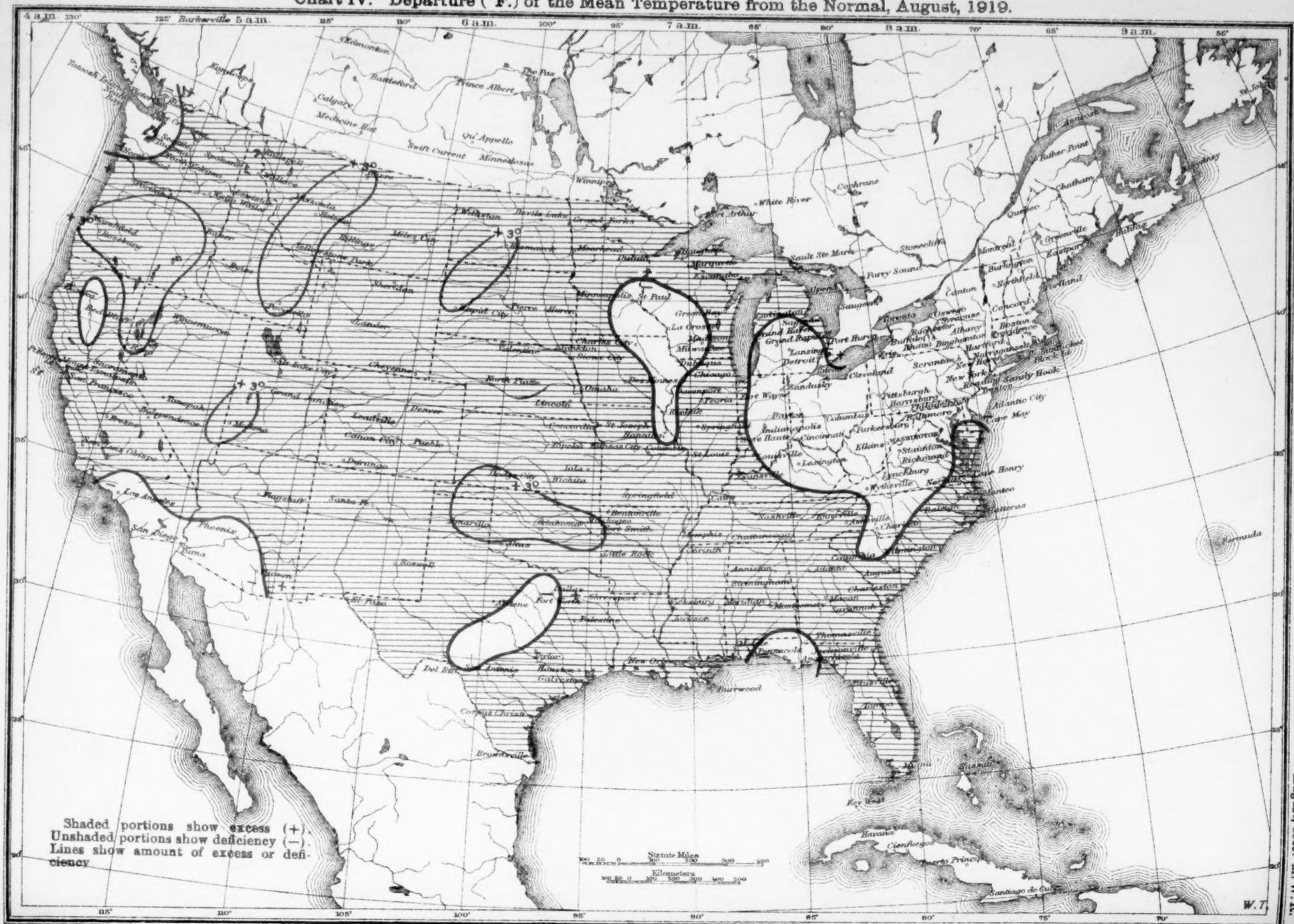


Chart V. Total Precipitation, Inches, August, 1919.

Chart V. Total Precipitation, Inches, August, 1919.

Chart VI. Percentage of Clear Sky between Sunrise and Sunset, August, 1919.

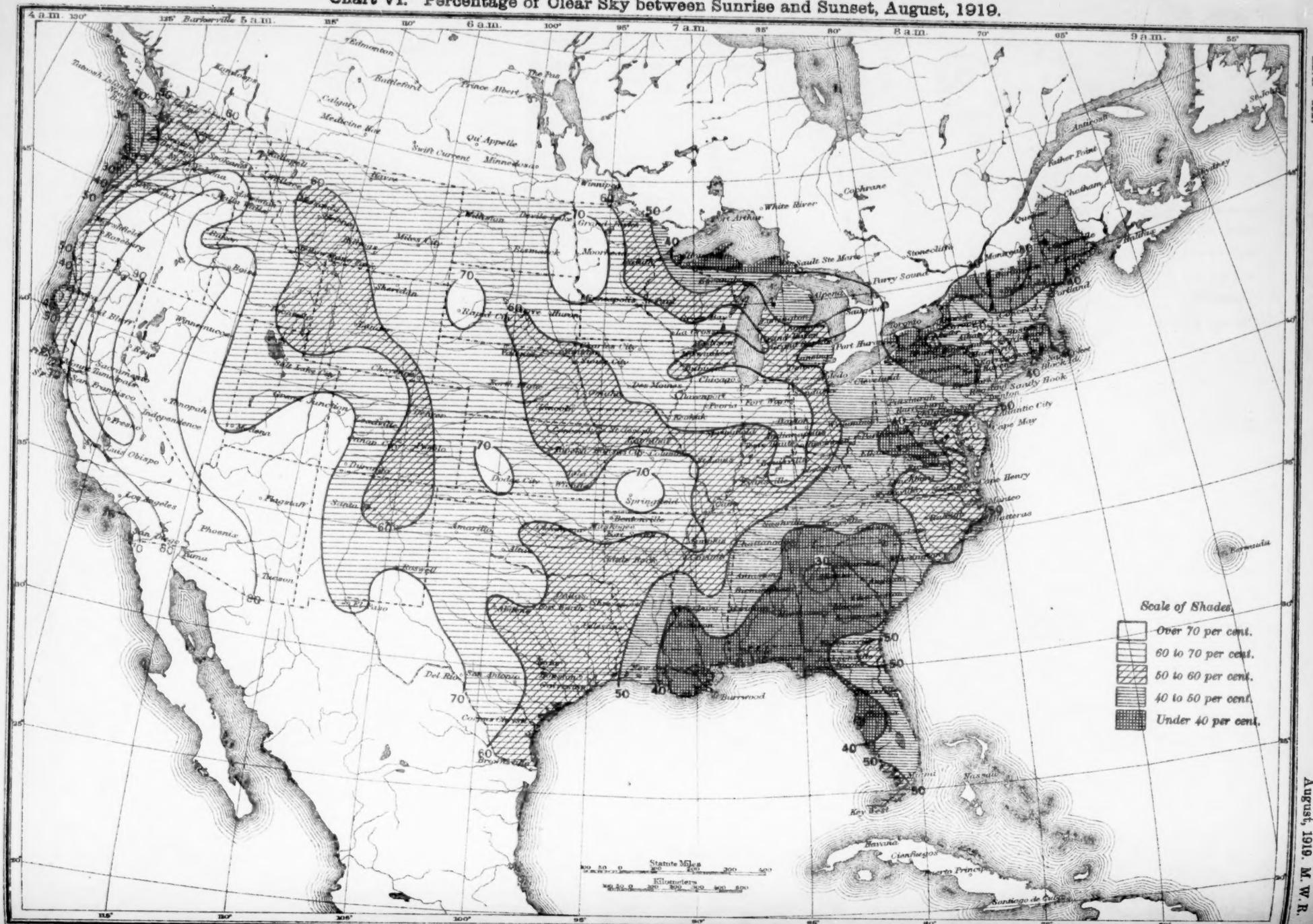


Chart VII. Isobars and Isotherms at Sealevel; Prevailing Winds, August, 1919.

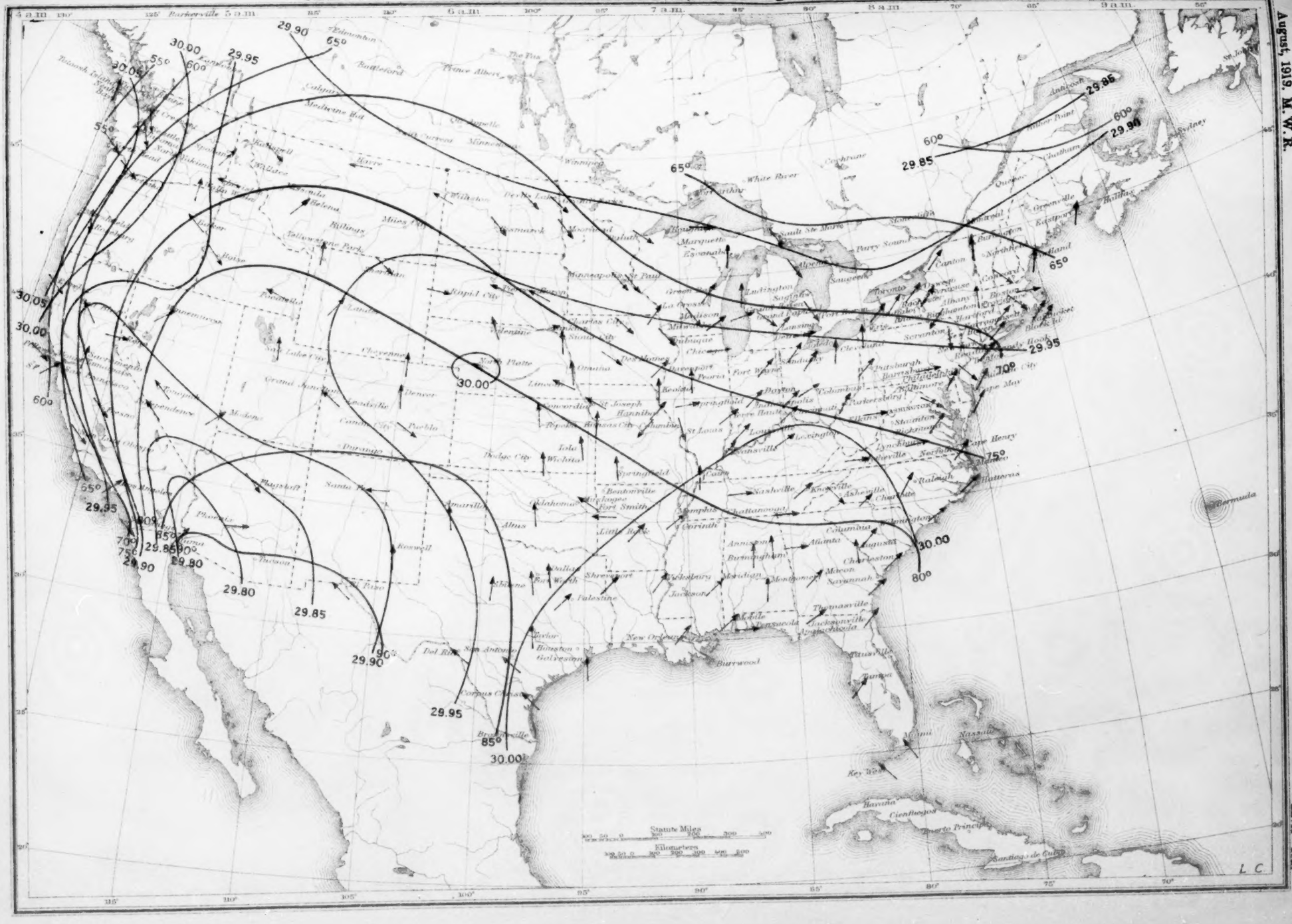
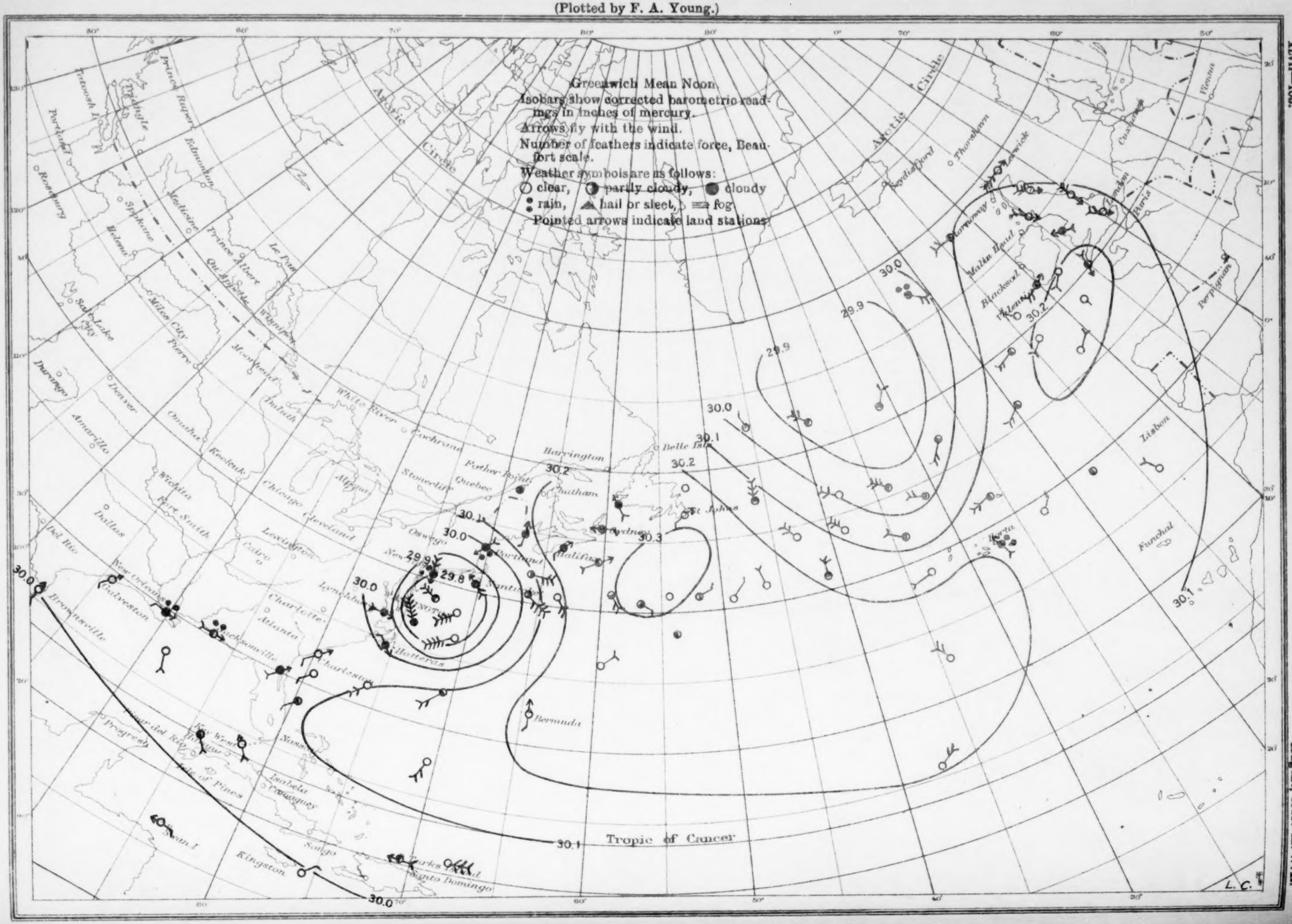


Chart IX. Weather Map of North Atlantic Ocean, August 14, 1919.

(Plotted by F. A. Young.)